DanSync: A Platform to Study Entrainment and Joint-Action during Spontaneous Dance in the Context of a Social Music Game

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Abstract. This paper presents a social music game, named DanSync, as a platform to study joint-action. This game context proves to be an effective manner to study spontaneous dance of players in a laboratory setting. Because of the gameplay participants are engaged in dancing to music with a strong motivation. Performance of dance synchronization to music is studied throughout the gameplay. Joint-action in a dyad is quantified in terms of correlation and phase-locking. Furthermore, entrainment and social bonding in small groups is studied by introducing perturbations in the music stimulus.

Keywords: Entrainment, gaming, music.

1 Introduction

A large body or research has explored entrainment, interpersonal synchronization and joint action in relation to each other (a number of comprehensive reviews include e.g. [1] for a dynamical systems approach; [2] for a review from an action simulation and motor resonance point of view; [3] for a review focused on joint action and social connection). A lot of this work has covered the perceptual and motoric basis for both interlimb and interpersonal coordination (see also [4]).

A number of main findings in previous work have been that people can (and often will unintentionally) synchronize their movements to movements that they see or hear others doing and the emerging social and physical factors that modulate the likelihood of interpersonal coordination.

There appears to be a clear link between the amount of (coordination dynamics-) information shared and frequency detuning; the larger the difference in eigenfrequencies between two systems, the stronger the informational link has to be to enable successful synchronization (e.g. [5]) as described in [1].

Most of this work, however, is done in controlled laboratory settings, and as such does not necessarily correspond to real-world behavior. Furthermore, most work thus far studies only behavior in dyads or solo, and does not make a comparison of solo, dyad and group in the same environment. Also, most of this work focuses on one typical movement, not on whole body movement.

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Several studies exist on the nature of social entrainment in cases where a group of people perform a common task and music is used to organize and coordinate the effortful activities [6]. There is evidence which suggests that action coordination is greatly dependent on whether the actors are trying to achieve a common goal; interacting in a competitive task is less likely to result in temporal coordination than interacting in a cooperative task [7]. Furthermore, social competence can predict coordination success in dyads [8].

Most studies are done with controlled temporal stimuli; metronome clicks etc, even though music provides a rich tool for studying these phenomena, its more ecological, its engaging, its multi-sensory (see also [9] for a multi-sensory experiment), and music can be competitive or cooperative. Also, music tightly connects these phenomena as it involves people synchronizing behavior to one another, people becoming entrained to both each others actions as well as to indirect results of actions (e.g. sounds in music), and it involves people coordinating their actions to perform together. In the past years, research in this field has focused on both controlled situations such as people tapping their fingers to an isochronous stimulus [10] and sporadically on more ecologically valid situations in which people for instance dance together in a room (e.g. [11]). All studies focus on one very specific movement, be it rocking motion [12,13], finger tapping [10], pendulum swinging [14]. Most of these behaviors are rather isolated, and do not always represent a real human interaction through full body movement, like e.g. dancing together or music production [15].

There have not been many studies that investigate the role of joint and individual goals in a social musical context. In this paper we present a novel way to empirically explore synchronization and entrainment aspects of dance in a social context. We developed a game in which 10 participants are motivated to dance in a spontaneous manner and to actively interact with other participants. This game is played in a setting resembling a club (including the lighting and a sound-system) but nevertheless is situated in our lab enabling a motion capture recording of all players present. In this study we explore the feasibility of the setup and analysis tools to provide further insights to the following aspects of joint-action and entrainment:

(1) Are people motivated in a social game context and dance in a spontaneous manner?

(2) Do people improve their synchronization over time and under of the influence of others?

(3) Is it possible to quantify social bonding and to optimize the conditions to maximize this effect?

This paper presents first the context of the experiment elaborating on the technical setup and the gameplay. In a following section the data analysis is explained followed by the results from this analysis. We conclude with a discussion and outlook.

2 Setup

The results presented in this paper are based on a social music game called DanSync which is played by a group of 10 participants. This game is developed through various iterations at our institute [16,17,18,19]. In what follows the technical setup is outlined followed by a description of the gameplay.

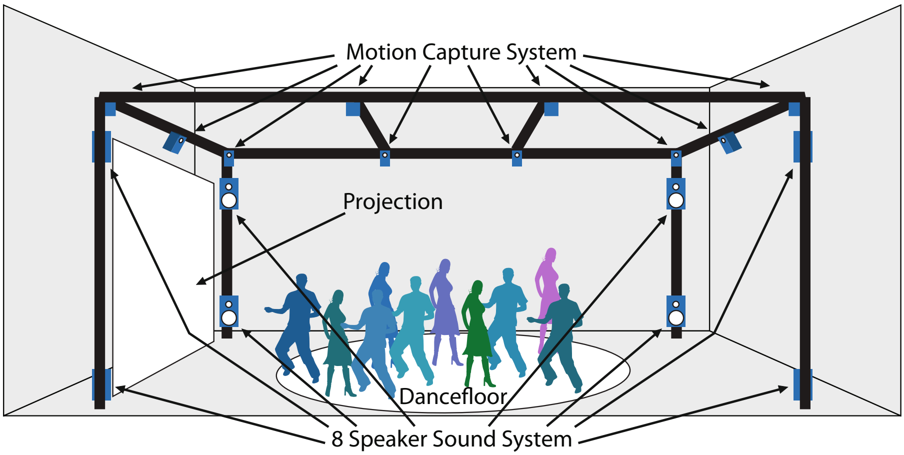

Fig. 1. A schematic overview of the different components of the setup used

2.1 Technical Setup

Various technologies are used in DanSync which are setup in a Truss structure of 5 m×5 m and 3 m of height as shown in figure 1. The dance movement of the players is measured with a Motion Capture (MoCap) system of Optitrack, Natural Point. With this MoCap system the 3D position of IR-reflective markers on a helmet worn on the head of 10 players is captured in real-time at a sampling frequency of 100 Hz. This data is sent via UDP to the central game computer running the game logics developed in Max/MSP and Jitter.

During gameplay the BPM of the movement of each participant is determined in real-time through the use of an FFT algorithm as described in detail in section 3.1. This BPM is compared to the BPM of the song played and a score is derived. All participants wear an iPod touch around their forearm in such a way that it is comfortable to wear and is easily visible during gameplay. This iPod touch receives real-time feedback from the central game computer via WiFi. In this way each participant has an individual feedback on their dance performance during the game. The central game computer plays back the music over an octafonic sound system and also projects visuals on the front wall of the dance arena. These visuals are used to instruct the participants on the gameplay before the game starts and presents an overview of the scores for all players after each round.

2.2 Gameplay

The DanSync game consists of 5 rounds schematically presented in figure 2.

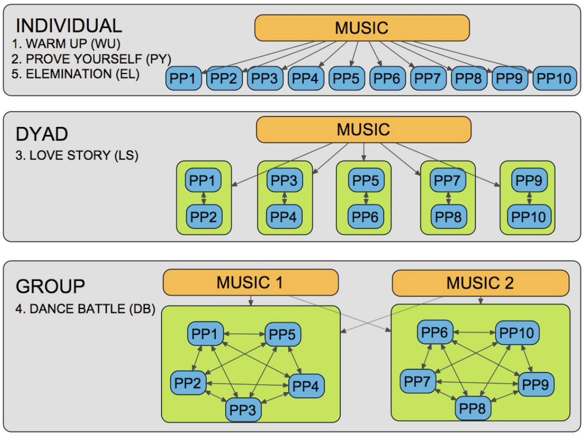

Fig. 2. A schematic overview of the different interaction models applied to the gameplay

1. WARM UP (WU): the first round of the game after receiving instructions on the gameplay. The goal is to synchronize dance movement to the tempo of the music but the scores obtained do not account for in the final score.
2. PROVE YOURSELF (PY): the task is the same as in the WU round, however, the obtained score is taken into account for the final score of the game.
3. LOVE STORY (LS): couples are formed by the game algorithm and the participants have to find their team mate based on the interpersonal distance visualized in real-time on their iPod. The task is to dance as close as possible as a couple to the tempo of the music.
4. DANCE BATTLE (DB): two teams of 5 players each are formed by the game algorithm and visualized as a blue and a red team on the projection on the front wall of the dance arena. 2 songs corresponding to each team are heard. On the iPod the team color is indicated together with a volume slider representing the loudness of the song at that time. Every 25 s one song is faded out together with a fade in of the song of the other team. The task is to dance to the music of your team and to keep on doing so even when the music of the other team is played.
5. ELIMINATION (EL): in this final round bad players are excluded one by one resulting in a single player at the end of the round who wins DanSync.

Each round takes approximately 3 minutes to play resulting in a 15 minute duration of the complete game. The songs played during the rounds were:
WU Don't Stop - The Subs (House, 128 BPM), PY Lonely Boy - The Black Keys (Rock, 84 BPM), LS Jolie Coquine - Caravan Palace (Charleston, 125 BPM), DB1 Acid Phase - Emmanuel Top (Techno, 134 BPM), DB2 Amphetamine - Drax LTD II (Techno, 142 BPM), EL Yeah 3x - Chris Brown (Pop, 130 BPM).

3 Data Analysis

This section presents concepts to quantify entrainment in relation to the music stimulus and to the other players. The input signal is the vertical position of the head of each participant at a sampling rate of 100 Hz. From this vertical displacement the tempo is determined on the one hand and the correlation and phase-lock is quantified on the other. These two analysis paths are described in detail in the following sections.

3.1 Synchronization to the Music

To study the amount of synchronization of the dance movement of the participants to the tempo of the music the vertical position of the head is used as an input signal. This signal is filtered by a bandpass filter in the range of 0.5 - 4 Hz corresponding to 30 BPM to 240 BPM respectively. From this signal the BPM value can be calculated using an FFT where 4 s of data is analyzed with an overlap of 2 s. The data contained within the 4 s under inspection corresponds to 400 data samples. This data is zero-padded to a total length of 6000 samples to obtain a resolution of 1 BPM in the frequency spectrum. In this spectrum the highest peak is located and the corresponding BPM value is determined.

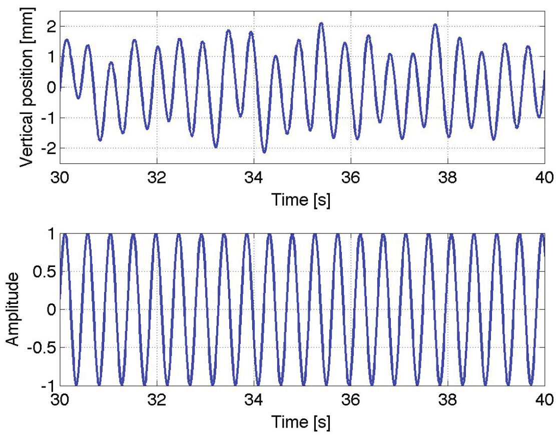

Fig. 3. Top: The vertical position of the head of a player after filtering. Bottom: A sinusoidal signal representing the tempo of the music.

To study the synchronization of the movement to the tempo of the music in more detail we make use of the cross-correlation of the filtered movement signal with a sinusoidal signal with the same frequency as the tempo of the music. Both signals are shown in figure 3.

The cross-correlation uses datawindows of 3 s (300 samples) with an overlap of 25% and lag values of 0.01 s (1 sample) in the range of ±2 s. In this way one can obtain a representation as shown in figure 4 where the x-axis represents time, the y-axis the lag and the color code the correlation value. The periodic structure in the vertical direction is due to the repetitive movement signal.

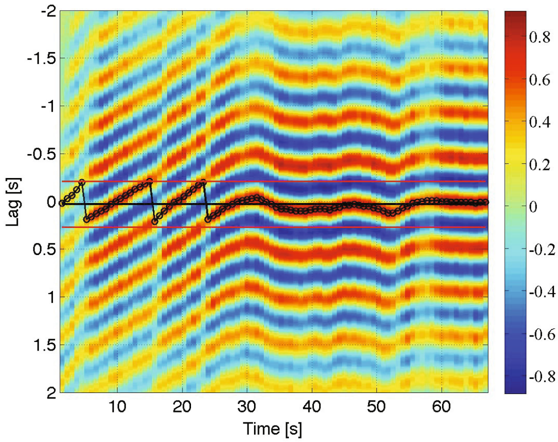

Fig. 4. The cross-correlation of headmovement with sinusoidal signal representing the tempo of the music. The points of maximal correlation are indicated by circles.

To further quantify this cross-correlation we make use of a peak-picking algorithm to locate the points of maximal correlation and their corresponding lag values (similar as in [20]). In order to obtain a more continuous path the maxima are located in an iterative process where the lag range is initiated at ± 2 s. Next the median of the lag values corresponding to the maximal correlation values is determined and a window of ± 0.5 times the BPM of the music is centered around this median defining the lag range in which the maxima are to be located in the next pass. The process is aborted when the lag range is unchanged since the last iteration and therefore an optimal result is obtained.

The peak-picking algorithm results in a set of maximal correlation values and their corresponding lags which are indicated with a circle in figure 4. The median is indicated with a horizontal black line and the window of ± 0.5 times the BPM of the music is indicated with the two horizontal red lines.

3.2 Interpersonal Coordination

The synchronization of individual players with other participants can be studied in the same way as described in the previous section. Here, the cross-correlation is calculated between the movement signals of both subjects under study. The peak-picking algorithm results in the maximal interpersonal correlation values and their corresponding lags.

4 Results

This section first presents the study of synchronization of dance movements to the music played and the interpersonal synchronization, followed by the effects of joint-action in a dyad and ends with an example of how the disturbance of an entrained system can be used to quantify social bonding.

All results presented are obtained in 4 test sessions where each time 10 players played the game DanSync. The last group of people played DanSync two times consecutively with a short break in between. The group of participants consisted of 10 male and 30 female subjects with an average age of $26,1 \pm 9,7$ years old.

4.1 Improvement of Synchronization to Music

To quantify the amount of synchronization of the players to the tempo of the music played we make use of the points of maximal correlation between the movement of all players and a sinusoidal signal representing the tempo of the music. When considering the 3 individual rounds of the game namely WU, PY and EL we can obtain 3 distributions for each time the game was played (5 times in total). These distributions are obtained by omitting the first 5 s to account for the time people need to start to synchronize. The data in the EL round is truncated to 45 s since this is the time when the first player is eliminated and the group decreases in number of players.

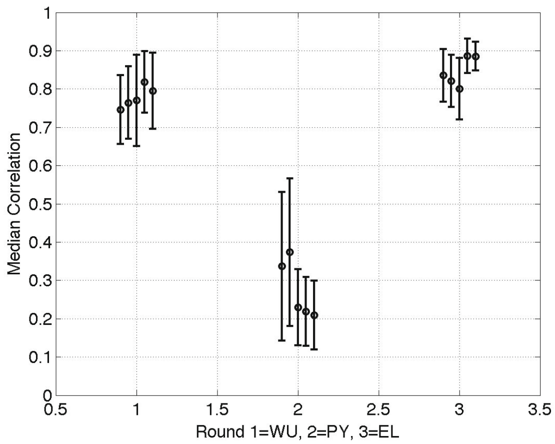

Fig. 5. The median of the correlation values for each group of participants for the 3 individual rounds WU, PY and EL. The errorbars represent the median absolute deviation.

Since the Lilliefors test rejects normality, we use the median instead of the mean value. As an error estimate we make use of the median absolute deviation or mad. The result is presented in figure 5.

In this figure we can clearly see similar correlation values for each game round for the different groups. The systematic difference between conditions is most likely due to the nature of the song. The Wilcoxon rank sum test rejects the hypothesis that the medians are the same between the first and last round making the high values in the last round significant. One can wonder if the high correlation values in the last song are due to the song or due to the motivating factor of the gameplay.

4.2 Improvement of Interpersonal Synchronization

To study the interpersonal coordination the correlations between the movements of the different subjects is calculated. For the individual rounds the correlation for each participant with all other players is calculated. In this way we can obtain 45 crosscorrelations for each unique pair within the 10 participants.

From the maximal correlation values obtained in each of the 45 crosscorrelations we take the median and represent them in a distribution. The normality was tested using a Lilliefors test and was accepted in all distributions. Next, the difference between distributions was tested using an ANOVA which resulted in a significant difference between all 3 distributions and a significant difference between the first and the last distribution. An example is shown in figure 6 for the first testsession.

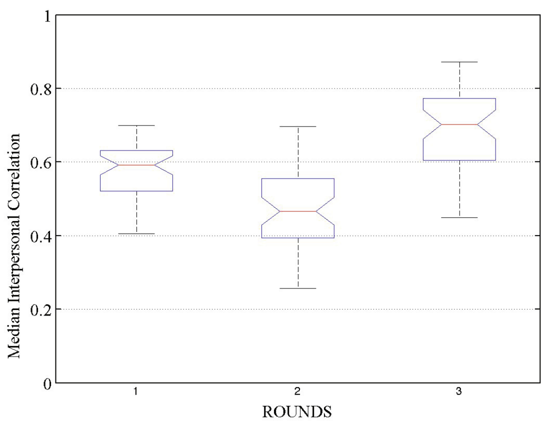

Fig. 6. ANOVA result of the distributions of the median of the maximal correlation values in each of the 45 possible crosscorrelations

From this analysis we can conclude that people dance in a more correlated manner with each other in the last round of the game. This is also the round where the highest correlation with the music was observed. One can raise the question wether an increased synchronization to a music stimulus induce social bonding or vice versa.

4.3 Joint-Action in a Pair (Dyad)

To study the joint-action in a dyad we make use of the data obtained in the LS round. The first 20 s of the data is omitted to account for the time the participants need to find their corresponding partner as assigned by the game logics. Using the median of the interpersonal correlation values and the mad of the corresponding lag values obtained through the peak-picking picking algorithm we can see a clear correlation as presented in figure 7. There is a clear correlation between the median correlation between players within a couple and the variation of their relative phase. In other words, the couples who have a clear phase-lock also correlate well or vice versa.

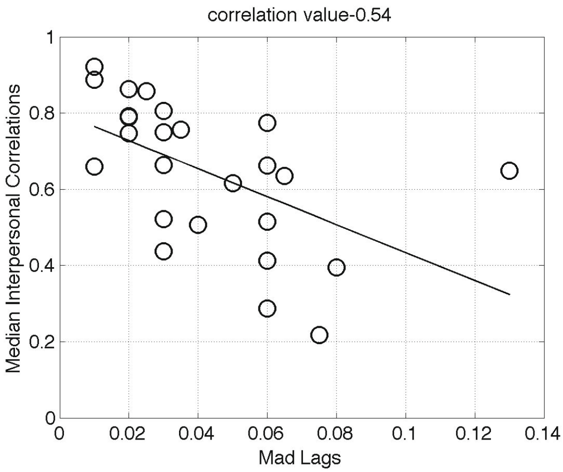

Fig. 7. Correlation between the median absolute deviation of the lags vs the median of the interpersonal correlation values for each dyad during the LS round

4.4 Joint-Action in a Group

To study joint-action in small groups of 5 participants the data in the DB round is analyzed. The BPM value of each participant is calculated for a timeframe of 4 s of data with an overlap of 2 s as described in section 3.1. The median and median absolute deviation of these BPM values is calculated for each timeframe under study and presented in figure 8 for a single group of participants. The red and blue datapoints correspond to the two teams. The horizontal straight lines correspond to the BPM value of the two songs. At the bottom of the figure the loudness of the songs played is shown where the lower value corresponds to silence and the top value is the nominal loudness.

Here we can see that the song of the blue team starts to play at the beginning of the round and both teams synchronize to that BPM. After 25 s the loudness of the song of the red team is at maximum and the song of the blue team is completely faded out. At this time both teams synchronize to the music of the

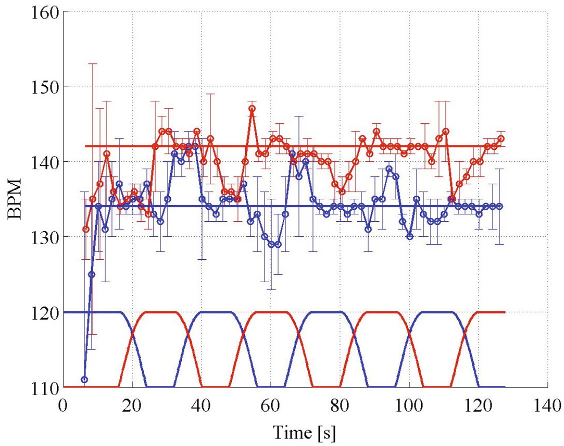

Fig. 8. An example of the performance during the dance battle round. A detailed explanation of the presented graphs is provided in the text.

red team while the goal of the game is to stay synchronized with the song of your own team. The same dynamics occur at 40 s. However, at the next cross-fade at 55 s the blue team manages to keep synchronized with its own song while the song of the red team sounds. This behavior is maintained throughout the remainder of the round with some perturbations in the synchronization.

The median BPM value of the group represents the synchronization to the musical tempo while the median absolute deviation resembles the amount of social bonding.

5 User Evaluation

After the game was played the 40 users where presented with a questionnaire probing their experience and their evaluation of the technology and gameplay. All participants found the game to be pleasant (82%) or very pleasant (18%). The majority of players found that dancing together was (very, 13%) motivating (78%) and the feedback presented on the projection and the iPod was experienced as (very, 25%) motivating (68%). Those players who rated their own performance as very good had high final score ($80,24 \pm 9,82$), those who rated their own performance as bad or very bad resulted with a low final score ($65,00 \pm 11,43$). A quarter of the participants found the motion capture helmet and the iPod as disturbing (25%) or very disturbing (0%). None of the participants found the projection disturbing. Most participants had danced better (88%) or much better (3%) due to the feedback on the iPod and the majority of the players found the added value of the iPod high (75%) or very high (10%). Almost all players found the feedback on the iPods sufficient (95%) and 35 participants found the feedback resembling their performance well (68%) or very well (20%). All players found the explanation of the game clear (60%) or very clear (40%) and the goal of each round was also clear (72%) or very clear (28%) for all participants. All participants would like to play the game again.

6 Discussion and Outlook

In this paper we presented a novel way to study entrainment to a music stimulus in a social game context. The game context provides an ecologically valid setting where participants can dance to music in a spontaneous manner with full body movements. The objective quantification of the users dance movements is made possible through the analysis of the vertical displacement of the head. The gameplay was experienced by the users as motivating and fun and the technologies used provided a clear added value to the dance performances of the players.

Our preliminary data shows a clear link between narrow phase distributions in dance tempos and interpersonal correlation in terms of median dance tempos as well as phase locking. This is in line with earlier findings on oscillator variability and entrainment described in e.g. [1].

The setup and the analysis tools presented in this paper allow us to present the data on a comprehensible level of interpretation on various aspects of social entrainment namely: synchronization of dance movements to music with a focus on the effect of the song and the effect of the social and game context, interpersonal synchronization and adaptation, joint-action in a dyad and in a group condition.

Related to the questions raised in the introduction we can state that:
(1) Based on the questionnaires conducted people are motivated in a social game context and dance in a spontaneous manner.
(2) Playing our game appears to increase the level of synchronization over the course of the different levels; further studies can clarify the roles of social bonding and interpersonal synchronization.
(3) It is possible to quantify social bonding using the tempo of the dance movements and the associated median and absolute median deviation.

We are convinced that future studies can focus on each of these aspects separately using the tools developed in this paper to research social entrainment in more detail.

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