Measuring and quantifying the impact of social interaction on listeners' movements to music

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Abstract. We empirically quantified the impact of a social factor on movements made by groups of adolescents while listening and responding to music. The methodology was based on motion capturing, using wireless Wii Nintendo Remote sensors, and subsequent statistical analysis. Participants moved along with the beat of the music in two different conditions, first blindfolded (individual) and then without blindfold (social) encouraging social interaction. Data analysis shows that there is a social factor which can be measured and quantified. Not only does the social context stimulate participants to synchronise better with and move more intense to the music, but it also increases the synchronisation of the movements between the individuals.

1 Introduction

Social interaction with music has been studied from different perspectives, including ethnomusicology [1,2], social psychology [3], and experimental psychology [4]. Empirical methodologies have been based on field observations [5], verbal questionnaires [6], and, more recently, experimental sampling methods [7,8]. Music thereby appears as a highly social phenomenon, rooted in human non-verbal and verbal communication. Its understanding has consequences for different fields such as music therapy, consumer behaviour, and music industry. Studies show that music can be used to improve peer interactions and meaningful play in children diagnosed with an autism spectrum disorder [9] and that it increases mood and social skills of individuals with acute and traumatic brain injury and stroke [10]. In-store experiments, for example, suggest that background music can be used to influence the average length of stay in a shop, the choice of one brand or style over another and the amount of money spent [11]. Besides this, there is a whole area of music related social activity on Internet [12]. However, many of these studies focus on individual subjects in their social context, rather than on the interactions between subjects, or they study social interaction on the basis of linguistic communication about music, rather than on the basis of non-linguistic forms of musical communication. The approaches are necessary, but not sufficient in terms of getting access to the physical and biological basis of social music interaction.

To gain more insight on how social interaction affects music perception and musical meaning formation, we adopt the paradigm of *embodied listening* in an individual blindfolded and in a social group condition. Although embodiment is a relatively unexplored paradigm in cognitive science [13,14], it is not entirely new to research on musical gesture and expressiveness. Reference can be made to the historical work of Truslit [15], Becking [16], Clynes [17], and to the more recent work of Camurri [18], Wanderley [19], Leman [20] and others. Recent work explores the use of video and sensing systems in order to capture body movement during musical activities. Recently, a number of studies have focused on gestural interaction between musicians [18,21].

In the embodied music cognition approach [22], the human body is seen as a mediator between meaning formation activities at the mental level, and musical signals at the physical level. Corporeal articulations are assumed to express the active personal involvement of a subject listening to music. This can be related to the perceived musical structure, and emotions that are attributed or experienced in response to music.

The approach also assumes that embodiment is a strong factor in the disambiguation of perceived musical structures. In this paper, we aim at extending this paradigm of embodied music cognition to the social interactive domain. We assume that through social interaction, corporeal responses can be perceived and picked up by other subjects that perform a similar task. If this task involves synchronisation of movements, and if the synchronisation movements of different participants influence each other, then we speak of *entrainment* [21]. Entrainment supposes interaction between the participants in a way that they will adjust their movements to each other and eventually 'lock in' to a common phase and/or periodicity.

In the past, research on music and movement made use of a wide range of materials, such as joysticks [23], laserpointers [24] or digital tablets [25]. All these technologies have limitations when larger groups of participants are involved. However, due to the development of low-cost wireless sensors it is possible to measure spontaneous human movements to music in ecological settings in a rather straightforward way. Not only do these sensors overcome the mobility limitations of previously used technologies, but they also allow for testing larger groups simultaneously. Interaction between participants and interaction with the music can be measured and quantified at the same time. Furthermore, based on real time data processing it is possible to develop interactive music applications. The use of wireless sensors also enables to step outside of the lab environment and implement experiments in a variety of settings.

While the use of new sensing technologies offers a lot of opportunities, the experimental methodology for studying the impact of social interaction on human movements to music still needs to be developed. Therefore, the goals of the present study are twofold, first, to investigate whether social factors can be measured and quantified in gestural responses to music, and second, to define a framework for the analysis of data which can be used in future experiments.

2 Experimental Setup

2.1 Participants

16 groups of 4 adolescents participated in this experiment (mean age 16, standard deviation 3). All participants were recruited from the third and fifth grade of several secondary schools in Flanders. It was requested that participants had normal hearing and normal motor abilities for inclusion in the study. The experiment included a pre-questionnaire, which aimed at gathering information about participant's age, gender, musical education and dance experience. There were 35 female and 29 male participants, of which 9 participants had a musical education.

2.2 Stimuli

Six excerpts, each with a duration of 30 seconds, were selected. The excerpts varied in tempo, level of familiarity and rhythmical ambiguity, and were presented with an intersection of 5 seconds pause. Three songs were chosen from the Flanders September 2007 hit list. It was assumed that these three songs would be very familiar to the teenage participants. The three unfamiliar excerpts comprised non-mainstream music (electronic/experimental, classical, non-western). It was assumed that this music would not be very familiar to the teenage participants. Furthermore, the six songs also varied in their level of rhythmical ambiguity. The rhythm of songs 3 and 5 allowed a binary or ternary interpretation, whereas song 2 had an unclear beat. Table 1 gives an overview of the 6 musical excerpts and their characteristics.

Table 1: Overview of the 6 musical excerpts used as stimuli in the experiment

Nr	Title	Performer	Tempo [BPM]	Familiarity	Rhythmical Ambiguity
1	Sunrise	Milk Inc.	140	Familiar	Unambiguous
2	Window Licker	Aphex Twin	123	Unfamiliar	Ambiguous

3	Follia	Anonymous	47/140,5	Unfamiliar	Ambiguous
4	Vietnam	Vorwerk	142	Familiar	Unambiguous
5	Unknown	Rashid Anas	72/216/146	Unfamiliar	Ambiguous
6	The way I are	Timbaland	115	Familiar	Unambiguous

2.3 Method and Equipment

Participants were given a wireless Wii Nintendo Remote sensor in the dominant hand and were asked to move along in synchrony with the beat of the six musical excerpts as shown in Figure 1. Each group had to perform this task in two conditions: individual, in which case participants were blindfolded, and social, without blindfolds and facing each other. Acceleration data were recorded on the hard drive of a PC, communicating with the Wii remotes via bluetooth. A Pd patch [26] was used to this purpose.

Figure 1: Group of participants performing the experiment in the social condition, with a Wii Nintendo Remote sensor in their dominant hand

3 Data processing

The data captured by the Wii Remote consists of three acceleration time series, one for each axis of the local reference frame of the accelerometer. These data were sampled at a rate of 100Hz. The data-analysis had a focus on (i) the amount of synchronisation of each participant with the music, (ii) the amount of movement intensity of each participant, and (iii) the synchronisation amount between participants (entrainment) without taking into account the synchronisation with the music.

3.1 Synchronisation analysis

In order to analyze the synchronisation with the beat, the amount of seconds the participants synchronized correctly with the music is calculated from the raw data. First, the three time series (three axes) are summed and the resulting signal is filtered to a 0.5Hz to 4Hz band. The filter eliminates the constant offset in the acceleration data due to the gravitation force, as well as the higher frequencies irrelevant to human rhythm perception (4Hz corresponds to a BPM-value of 240). In a next step, the dominant frequency component (beat) in the movement is calculated for each block of 2 seconds by applying a FFT over a 4-second moving window with a 2-second overlap. The dominant peak in the Fourier spectrum is identified and compared with the nominal BPM of the excerpt, allowing a tolerance of ±5BPM for deciding on correctness of synchronisation. Also the half and the double of the nominal tempo are considered, with tolerance windows of ±2.5 BPM and ±10 BPM, respectively. The result of this calculation is defined as the number of 2-second blocks in which the participant succesfully synchronized with the music [26].

3.2 Intensity of movement analysis

In the second approach, the raw data are converted to a measure for the intensity of the participant's movements. This is done through Eq. (1), giving the cumulative sum of the norms of the acceleration differences for each two consecutive samples in the 30 second series (3000 samples, at 100Hz).

$$I = \sum_{i=1}^{2999} \sqrt{\left(a_x(t_{i+1}) - a_x(t_i)\right)^2 + \left(a_y(t_{i+1}) - a_y(t_i)\right)^2 + \left(a_z(t_{i+1}) - a_z(t_i)\right)^2} \quad (1)$$

The resulting single number is a measure for the intensity of the movements of the participant: the more intense the movements, the larger the differences in acceleration between consecutive samples will be, resulting in a larger cumulative sum over the excerpt. For each participant, the resulting intensity for each excerpt (and for each condition) is normalized over the mean of the intensities over all excerpts for that participant. This corrects for a 'natural' difference in intensity of movement between the participants, as in this experiment the primary concern is the influence of the condition (individual vs. social) and the influence of factors such as the musical characteristics of the excerpts.

3.3 Entrainment analysis

To analyze the entrainment between participants in a group, the norm of the raw data is taken (Eq. (2)) and the resulting time series are statistically processed.

$$A(t_i) = \sqrt{a_x^{\,2}(t_i) + a_y^{\,2}(t_i) + a_z^{\,2}(t_i)} \quad (2)$$

The intra group correlation is calculated as a measure for group interaction (entrainment). From the selected data the overall within group (inter subject) correlation is defined as the average of the 6 possible pairs of inter-subject paired correlations by condition, group and song. Correlations are calculated on the normalized detrended total acceleration in the [5s,25s] time interval.

4 Results

Prior to analysis a Modified Levene test and a Kolmogorov-Smirnov test (KS-test) were used to check for homogeneity of variances and normality. Both assumptions could be accepted enabling an ANOVA-analysis for both synchronisation and intensity of movement data.

For the synchronisation with the music, the results summarized in Table 2 show that participants synchronise significantly better in the social condition in comparison to the individual condition ($p < .05$, $\alpha = 0.05$). The main effects are visualised in an interaction plot in Figure 2, which shows that the mean synchronisation is higher in the social condition for all songs. Statistical analysis shows that the songs themselves have a great impact on the synchronisation results, which is also evident from Figure 2. A multiple comparison Tukey analysis shows that participants score significantly lower for songs 3 and 5 than for songs 1, 4 and 6. As songs 3 and 5 are the unfamiliar excerpts with a rhythmical ambiguity, these characteristics of the music clearly have an impact on the difficulty the participants experience in synchronizing with the beat. Songs 3 and 5 can be interpreted either binary or ternary, whereas songs 1, 4 and 6 are pop songs with a clear beat. Furthermore, for song 2, an unfamiliar excerpt with an unclear beat, the Tukey analysis shows the scores lie in between the scores for the ambiguous and the pop songs.

Results of the ANOVA analysis on the intensity of movement data are shown in Table 3. Participants move significantly more intense in the social condition ($p < .05$; $\alpha = 0.05$) for all songs. These results are visualised in the interaction plot in Figure 3. Not only do the participants synchronize better with the music in the social condition, they also move more intensely.
For the intensity of movement, again there is a definite impact of songs themselves. In this case however, a multiple comparison Tukey analysis did not reveal subgroups in

the influence of songs with respect to rhythmical ambiguity and familiarity and it is yet unclear which characteristics of the songs are dominant.

Table 2: Overview of the results of the ANOVA-analysis on the synchronisation data for the variable Condition

ANOVA: synchronisation		
	F-value	**p-value**
Song1	2.40	0.12
Song2	10.13	<.01
Song3	5.37	<.05
Song4	5.69	<.05
Song5	9.46	<.01
Song6	6.97	<.01

Table 3: Overview of the results of the ANOVA-analysis on the intensity of movement data for the variable Condition

ANOVA: intensity of movement		
	F-value	**p-value**
Song1	20.06	<.01
Song2	66.13	<.01
Song3	26.53	<.01
Song4	41.09	<.01
Song5	46.40	<.01
Song6	45.61	<.01

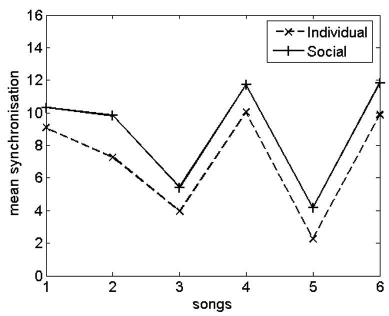

Figure 2: Visualisation of the mean synchronisation results per song in the individual and the social condition

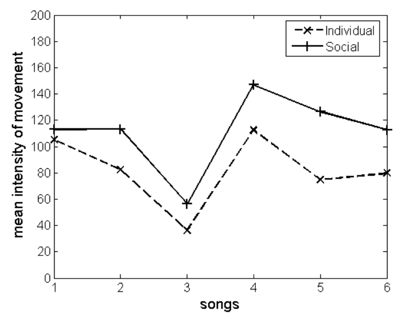

Figure 3: Visualisation of the mean intensity of movement data per song in the individual and the social condition

To test whether the participants also synchronize their movements with each other in the social condition, the within-group correlations of the acceleration data are statistically analyzed. Figure 4 plots the average within-group correlations in both conditions for each song. The results reveal that there is an overall increase of correlations for all songs in the social context. Although the correlations are not very pronounced, the fraction of significant correlations is high and again depends on the song.

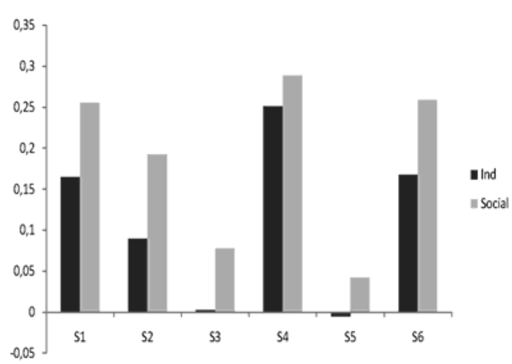

Figure 4: Bar chart with the results of the within-group correlations per song in the individual and the social condition

5 Discussion

There is a significant difference in gestural response to musical stimuli in a social compared to an individual context. However, it could be premature to conclude that this is solely due to the social impact. Since all participants carried out the experiment in the same order, first the individual and then the social condition, it is impossible to distinguish between the impact of a learning process and the impact of the social context. To eliminate this problem, 16 other groups of 4 participants (mean age 16, standard deviation 3) carried out the experiment only in the second, social condition, so that no learning process could take place. We hypothesize that if the synchronisation and intensity of movement results are immediately as high as the second trial of the first set of participants, then it is the social context that stimulates to synchronise better and move more intense to the music. If, however, the synchronisation and intensity of movement results would be at the level of the first trial, then we should conclude that the improvement is caused by learning processes and familiarity with the task.

The mean synchronisation results for this set of participants are shown in Figure 5, where the data are compared with the results for the participants that performed the experiment in both conditions (Figure 2). It can be observed that there is no significant difference in synchronisation results in both social conditions (except for song 1), which confirms the assumption that social context did indeed stimulate the participants to synchronise better with the beat of the music. Similarly, Figure 6 shows the interaction plot for the mean intensity of movement. Again, the result confirms that the social context did stimulate the participants to move more intense to the music, although other effects seem to have impact as well.

The present study was carried out in the context of a large fair. This forced us to design an experiment with blindfolded subjects in the individual condition, rather than letting (unblindfolded) individual subjects move in separate rooms or boxes where they could not see each other. Indeed, one could argue that deprivation of sight has an effect on movement, in the sense that participants may feel more restrained and limited in their movements. Therefore, it could be that the present results are in fact the reflection of this deprivation of sight, rather than an effect of social condition. To test for this, it would be necessary to compare our data with non-blindfolded individuals, or redo the experiment with non-blindfolded individual conditions. So far, this comparison has only been done with children from a different age [27]. The results seem to indicate that the lower score of the individual condition is not only due to deprivation of sight. Data with children from 7 and 9 years old show that there is indeed an effect of social interaction. Furthermore, it can indeed be argued that synchronisation with the beat of the music can be done blindfolded. It is to be expected that the main effect of being blindfolded is on movement intensity, rather than on synchronisation with the beat of the music. This may explain the difference between the two social conditions in Figure 6. However, further study is needed to sort out these alternatives.

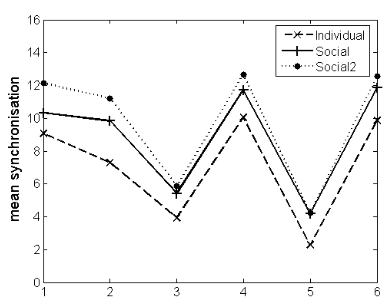

Figure 5: Interaction plot of the mean synchronisation results per song in the individual and the social condition of the first 16 groups in comparison to the social condition (Social2) of the second 16 groups

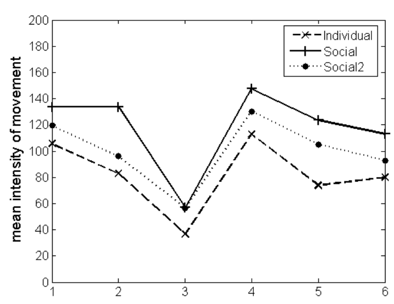

Figure 6: Interaction plot of the mean intensity of movement data per song in the individual and the social condition of the first 16 groups in comparison to the social condition of the second 16 groups (Social2)

6 Conclusion

Wireless motion sensors and new analysis methods were used to measure and quantify how subjects move in response to music. An experiment with groups of adolescents shows a significantly improved synchronisation with the beat of the music in a social context compared to individual movements. Additionally, the participants also move significantly more intense in a group situation. Furthermore, a positive shift was established in within-group correlations of the movements of the participants. The main aim of this study was (i) to experiment and develop a methodology for measuring and quantifying human movements to music and (ii) to study the influence of the social context using wireless acceleration technology. Additionally, insight was gained in how to improve the experimental setup. This methodology can now be used in future experiments with specific target groups for studying influence of social context on musical gestures, music perception and musical meaning formation. These insights can lead to new applications in various fields, such as music education, music therapy and music production.

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