

Quantifying Children's Embodiment of Musical Rhythm in Individual and Group Settings

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ABSTRACT

We empirically quantified the impact of social interaction on movements made by children while listening and responding to music. The methodology was based on wireless motion capturing, using Wii Nintendo Remote sensors, and subsequent statistical analysis. We investigated intensity of movement and the amount of synchronization with the beat in two conditions: individual, separated by screens, and social, moving together in groups of four encouraging social interaction. Data analysis showed that there is a social embodiment factor which can be measured and quantified. Furthermore there is also an effect found of the type of music on the gesture response, both in the individual and social context of the experiment.

INTRODUCTION

From birth, children are immersed in everyday musical worlds mediated increasingly by digital technologies. Many young children experience and deal with digital music on a daily basis. Music has become a virtual object, which can be easily retrieved, manipulated and shared. These contemporary forms of musical practice and the technologies associated with them undoubtedly have an impact on how people perceive and deal with music and also create new social ways of exchanging, manipulating and experiencing music. These profound changes required for a new discourse on listening, experiencing and practicing music. Hence, research on how individual and social music perception and musical experiences are affected by this digital revolution is necessary. In-depth insight in the effect of new technologies on musical meaning formation processes can contribute to a wide range of fields, such as music education, music therapy, entertainment and music industry, as well as to sports and revalidation. Research on how the new technologies can be applied in these fields only recently gained more attention (Webster, 2002). Nonetheless, recent developments in the fields of movement analysis and gesture capture technology create appealing opportunities for music pedagogy and related fields. Research by Pachet (2003, 2006) has already shown that *The Continuator*, a music technological device enabling child/machine interaction and creative musical processes in young children, enhances the musical invention and exploration in classroom settings (Pachet & Adessi, 2005). More recently Bevilacqua et al. (2007) showed promising results in an experiment with a gestural interface to support music pedagogy, based on wireless sensors including accelerometers and gyroscopes.

The development of new technologies not only contributes to new music applications, but also opens up a range of opportunities in music research, and in particular to the research on music and movement, and music and social interaction. In the past, music researchers already made use of a wide variety of materials, such as joysticks (Styns & van Noorden, 2006), laserpointers (Camurri et al., 2006) and digital tablets (Godøy & Jensenius, 2006), but all these technologies have limitations when larger groups of participants are involved. Due to the development of low-cost wireless sensors it is now possible to test larger groups of participants simultaneously. Moreover, these new capture technologies allow 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, they also allow to step outside the laboratory environment and implement experiments in natural environments. Hence, it is now possible to study the relationship between music and social interaction in ecologically valid situations in an empirical and quantifiable way. The resulting insights can then again contribute to the development of new pedagogical, therapeutic and other applications.

Before the availability of these measurable and quantifiable methods, the relationship between social interaction and music has already been studied from different perspectives, including ethnomusicology (Merriam, 1964; Nettl, 2000), social psychology (Hargreaves & North, 1997) and experimental psychology (De la Motte-Haber, 1999). Empirical methods were based on field observations (Lortat-Jacob, 1979), verbal questionnaires (Juslin et al., 2005), and more recently, experimental sampling methods (Sloboda et al., 2001). 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 nonlinguistic forms of musical communication. Thus these methods do not succeed to get 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 versus a social group condition. Although embodiment is a relatively unexplored paradigm in cognitive science (Varela et al., 1991; Gallagher & Cole, 1995), it is not entirely new to research on musical gesture and expressiveness. Reference can be made to the historical work of Truslit (1938), Becking (1958) and

Clynes (1977), and to the more recent work of Camurri (2007), Wanderley (2000), Leman (2007) and others. Recent work explores the use of video and sensing systems in order to capture body movement during musical activities.

In the embodied music cognition approach, the human body is seen as a mediator between meaning formation activities at the mental level, and musical signals at the physical level. In this view, corporeal articulations are interpreted as an active personal involvement of a subject listening to music. This expression can be related to the perceived musical structure and to emotions experienced in response to music. In the present 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. Through this social interaction process, subjects can influence each others movements, such as enhance or decline other subjects' synchronization or increase each others movement intensity.

The research presented in this paper is an exploratory study, using new sensing technologies and statistical methods to investigate the impact of social interaction on children's movements to music in an objective way. This study is a first step towards more profound research on the impact of social interaction on children's embodiment to music and can lead to more insight in the social processes involved in musical meaning formation and to the development of applications in music education, music therapy and revalidation.

EXPERIMENTAL SETUP

A. Participants

14 groups of 4 participants participated in this experiment (mean age 9, standard deviation 1). All participants were recruited from the 3rd and 5th grade of a primary school 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, aimed at gathering information about participants' age, gender, musical education and dance experience. There were 33 female and 23 male participants, of which 11 participants were enrolled in a music school at the time of the experiment.

B. Stimuli

Ten musical 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. Familiarity of the songs was established using a questionnaire in the participating classes, previous to the experiment. Furthermore, the ten songs also varied in their level of rhythmical ambiguity. The rhythm of song 3 allowed a binary or ternary interpretation, whereas songs 6, 8 and 9 had an unclear beat. Table 1 gives an overview of the 10 musical excerpts and their characteristics.

Table 1. Overview of the 10 musical excerpts used as stimuli in the experiment. The column 'Level' stands for the level of Familiarity (F=familiar; Uf = Unfamiliar) and level of Rhythmical ambiguity (A=Ambiguous) of the excerpts.

Nr	Title	Performer	Tempo (BPM)	Level
1	Relax	Mika	122	F
2	Spraakwater	Extince	90	Uf
3	Unknown	Rachid Anas	72/146/216	Uf / A
4	Freefall	Jeckyll & Hyde	143	F
5	Kaantalaga	DJ Doll Remix	122	Uf
6	March of the Pigs	Nine Inch Nails	133	Uf / A
7	Say yeah!	Morning Musume	143	Uf
8	Window Licker	Aphex Twin	123	Uf / A
9	Hiyamikachi Bushi	Traditional	143	Uf / A
10	Straight to the bank	50 cent	89	F

C. 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 ten musical excerpts. Each group had to perform this task in two conditions: individual, in which case participants were separated using screens, and social, moving together in groups of four and facing each other. All groups performed the task during three trials, of which two were individual and one was social. Half of the groups performed the task first two trials individually and the third trial social (IIS), the other 7 groups performed the task first individually, then social and the third trial again individually (ISI). This randomisation was used to be able to distinguish between the impact of the social context and the impact of learning effects.

Acceleration data were recorded on the hard drive of a PC, communicating with the Wii remotes via bluetooth. A Pd patch (Demey et al., 2008) was used to this purpose. The whole experiment was also recorded on video, for further interpretation of the data.



Figure 1. Group of participants performing the experiment in the individual condition, separated by screens, with a Wii Nintendo Remote in their dominant hand.



Figure 2. Group of participants performing the experiment in the social condition, facing each other, with a Wii Nintendo Remote in their dominant hand.

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 synchronization of each participant with the music, (ii) the amount of movement intensity of each participant.

A. Synchronization analysis

To analyze the individual synchronization with the beat of the music, 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 up 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 $\pm 5\text{BPM}$ for deciding on correctness of synchronization. Also the half and the double of the nominal tempo are considered, with tolerance windows of $\pm 2.5\text{BPM}$ and $\pm 10\text{BPM}$, respectively. The result of this calculation is defined as the number of 2-second blocks in which the participant successfully synchronized with the music (Demey et al., 2008).

B. 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).

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

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.

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 synchronization with the music, the results show that participants did not synchronize significantly better in the social condition in comparison to the individual condition ($p < .05$, $\alpha = 0.05$) (Figure 3). This contradicts earlier findings (De Bruyn et al., 2008) that with adolescents (mean age 16, standard deviation 3) synchronization with the beat of the music did improve significantly from the individual to the social condition. Statistical results did show that the songs themselves, more particularly the complexity of the songs, have a great impact on the synchronization results in both conditions, which is also evident from Figure 3. A multiple comparison Tukey analysis shows that participants score significantly lower for songs 3, 6, 8 and 9 than for songs 1, 2, 4, 5, 7 and 10. As songs 3, 6, 8 and 9 were the songs with an ambiguous rhythm, this characteristic of the music clearly has an impact on the difficulty the participants experience in synchronizing with the beat. Familiarity with the songs did not have a significant impact on the synchronization results.

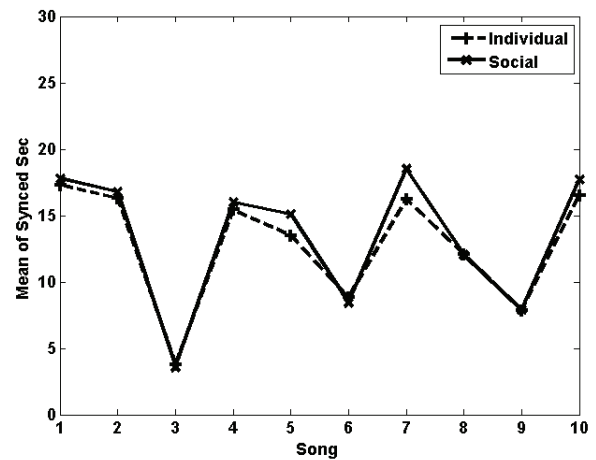


Figure 3. Visualisation of the mean synchronisation results per song in the individual and the social condition.

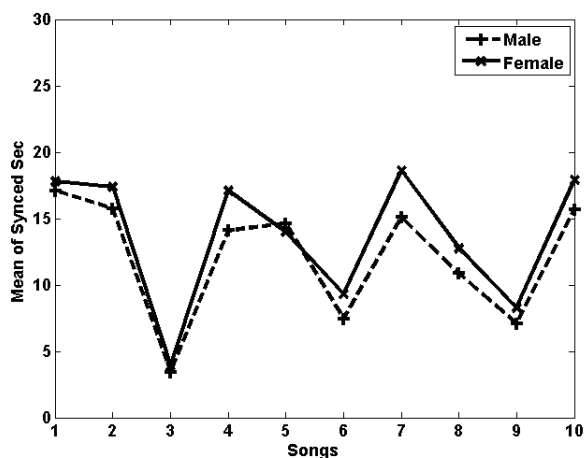


Figure 4. Visualization of the mean synchronization results per song for males and females.

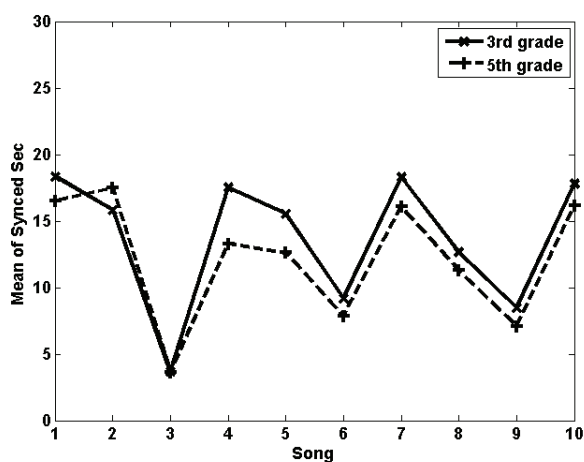


Figure 5. Visualization of the mean synchronization results per song from the 3rd grade and the 5th grade.

Surprisingly, music education did not have an effect on the synchronization scores. We did find a tendency, though not statistically significant, for girls to synchronize better as well as for the 3rd grade children compared to the 5th grade (Figure 4, Figure 5).

For the intensity of movement, the results summarized in Table 2 show that participants move significantly more intense in the social condition ($p < .05$, $\alpha = 0.05$) compared to the individual condition. The main effects are visualized in an interaction plot in Figure 6. 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. Music education and gender, nor age had a significant impact on the intensity of the movements of the participants.

As a first conclusion, the analysis showed that the social context did not have an effect on the synchronization with the beat of the music, but did cause an increase in movement

intensity. In other words, the children did not synchronize better in the social condition, but they did move more intense. However, the design of the experiment could have an effect on this increase in movement intensity; in particular a learning effect over the trials could be the cause of this increase in the intensity of the movements. Hence, using ANOVA and multiple comparison Tukey analysis, we investigated the effect of the order of the trials (IIS or ISI) on the movement intensity.

Table 2. 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
Song 1	36,94	<.01
Song 2	14,75	<.01
Song 3	17,18	<.01
Song 4	26,72	<.01
Song 5	16,09	<.01
Song 6	29,06	<.01
Song 7	18,37	<.01
Song 8	15,81	<.01
Song 9	10,62	<.01
Song 10	8,83	<.01

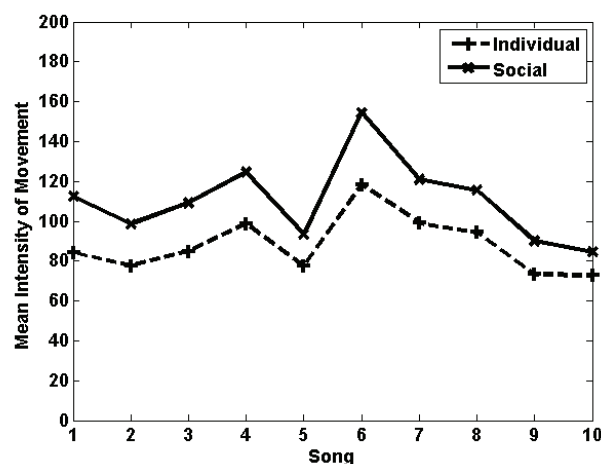


Figure 6. Visualisation of the mean intensity of movement data per song in the individual and the social condition.

This analysis shows that for the IIS design there is a significant difference in mean intensity of movement between trials. The main effects are visualized in Figure 7, showing that the intensity of movement increases quasi linear over the trials. This suggests that the increase of movement intensity is caused by learning effects, more than by the social context. Analysis of the data from the ISI design is clearly different from the IIS design (see Figure 8). Here we no longer see a linear increase of the movement intensity over the trials, showing that the social condition in the second trial does indeed have an impact on the corporeal experience of the participants. For songs 1, 2, 3 and 7 we see that the movement intensity is highest in the social condition. For songs 4, 5, 6 and 8 we see an increase from the first individual trial to the second social trial and then the movement intensity stabilizes in the third individual trial,

which can be explained by the fact that participants imitate movements in the third individual trial that they saw and did in the second social trial. Hence, we can conclude that the social context does indeed have an impact on how participants embody the music.

DISCUSSION

The present research has shown that there is a social embodiment factor which can be measured and quantified. The children did not synchronize better in the social condition, but the social context did stimulate them to move more intense to the music. These results partly confirm results of a previous study on the impact of social factors on rhythmical synchronization in adolescents (De Bruyn et al., 2008). That study showed that participants (mean age 16, stdev 3) synchronized better in the social condition and also moved significantly more intense in a social context. The fact that in the present experiment with younger children no improved synchronization can be found in the social condition can have various causes, such as level of difficulty of the task, social development of the child, motor development of the child and others. However, it should be noted that, at this time, only hand movements are registered. In previous experiments with adolescents and adults this never seemed to cause difficulties in interpretation since these participants kept very well to the given task (synchronize your hand with the beat of the music). In the present experiment with children, video data show that the participants performed the task very freely, they began dancing and jumping around, resulting in more synchronization in the legs and less movements with the hand. Hence, in future experiments the amount of sensors per participant should be increased, registering both leg and hand movements.

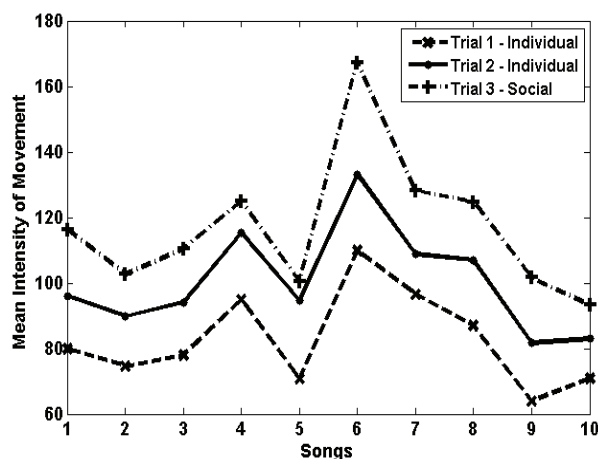


Figure 7. Interaction plot visualising the mean intensity of movement data per song for the 3 trials in the IIS design.

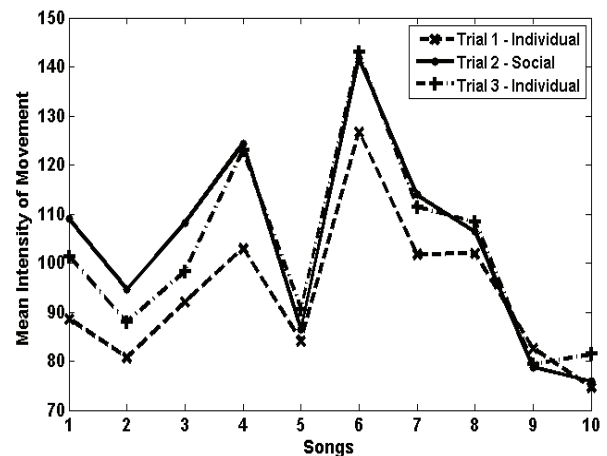


Figure 8. Interaction plot visualising the mean intensity of movement data per song for the 3 trials in the ISI design.

In the analysis we also took into account the impact of covariates (age, gender and music education) on the embodiment of the participants. These analyses show that age did not have a significant impact on synchronisation nor on intensity of movement. This can be explained by the small age difference between the groups, namely 8 and 10 years old. In future experiments comparison will be made with embodiment data of other age groups. We also investigated the impact of music education, and again we could conclude that musical background did not have an impact on synchronisation and intensity results. However, here it should be noted that the participants in this experiment could not have had many years of musical education considering their age. Furthermore, there was a great unbalance between the amount of participants enrolled in a music school (11) and those with no musical background (44). Finally, we also looked at the impact of gender on musical embodiment. Although not statistically significant, we could see a tendency for girls to synchronise better than boys, whereas boys tended to move more intense in comparison to the girls. Interpretation of the video data showed that girls were very focused on a good execution of the given task, while boys were more involved in spontaneous movements meant to impress the other participants, rather than in the actual synchronization task.

CONCLUSION

This study, using wireless motion sensors and new analysis methods, shows that there is a social embodiment factor which can be measured and quantified. An experiment with groups of primary school children shows a significant increase of intensity of movement when moving to music in a social context compared to individual movements. Additionally, we also found an effect of the type of music on the gesture response, both in the individual and social context of the experiment.

ACKNOWLEDGMENT

L. De Bruyn acknowledges the Ghent University BOF fund for a doctoral grant. The authors also wish to thank the primary school Henri D'Haese of Gentbrugge, and in particular the head of the school Frank Henry and the teachers Ann Trouvé and Iris Bouché, for allowing their pupils to participate in this experiment. We also wish to thank Dr. Michiel Demey, Frank Desmet and Ivan Schepers for their support in this research.

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