Embodiment, Emotion and Social Bonding on the Dancefloor: Initial Findings from a Replica Club Study

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Abstract

Participating in electronic dance music (EDM) events fosters feelings of community and connectedness and is associated with strong emotional experiences (Cannon & Greasley, 2021). With syncopated rhythms promoting entrainment to the beat, EDM enables interpersonal synchrony, which enhances social bonding (Tarr et al., 2016). On the dancefloor, rhythmic entrainment may create a sense of continuous, embodied pleasure that is conveyed to others via dance movement, resulting in collective emotional experiences (Witek, 2017). Despite evidence of these processes in research on subjective accounts of EDM participation, the interrelations between emotional and interpersonal synchrony and their contributions to social bonding in an EDM context are yet to be systematically examined. This preliminary study trialled a quantitative methodological approach to assess how EDM events facilitate social connectedness through shared movement and emotional experiences on a real-world dancefloor. A small group of participants ($N = 5$) danced to a DJ mix in a replica club environment while accelerometers measured their movement. Social bonding was assessed before and after the event, and emotional experiences (emotional contagion, *kama muta*, perceived emotional synchrony and embodied pleasure) were measured post-event. Preliminary results reveal increased social bonding scores following group dance to EDM, and evidence of embodied pleasure, emotional contagion and rhythmic entrainment on the dancefloor, shown by Fourier analysis of accelerometer data. Findings are discussed in relation to implications for follow-up research.

Keywords: entrainment, synchrony, social bonding, emotion, electronic dance music

Introduction

Electronic dance music (EDM) is designed for the dancefloor. It is characterised by inherent rhythmic properties, such as the repetitive drum pattern and high pulse clarity, which promote movement (Burger & Toiviainen, 2020; Zeiner-Henriksen, 2010). It is a prime example of 'groovy' music, facilitating entrainment through optimum levels of rhythmic syncopation (Witek et al., 2014). This, in turn, leads to interpersonal synchronisation amongst a group of dancers and has been observed in studies in which movement is measured amongst participants on real-world dancefloors (Ellamil et al., 2016; Solberg & Jensenius, 2017). Interpersonal synchrony is positively related to social bonding across many experimental studies both in musical and non-music contexts (e.g. Bamford et al., 2023; Hove & Risen, 2009; Stupacher et al., 2017; Tarr et al., 2016; Wiltermuth & Heath, 2009). In the context of research on subjective experiences of EDM event participation, which reveals associations between participation at EDM events and social connection (e.g. Cannon & Greasley, 2021; Kavanaugh & Anderson, 2008; Little et al., 2018; Riley et al., 2010; Takahasi & Olaveson, 2003), this leads one to consider how embodied processes (i.e. entrainment and interpersonal synchronisation) on the dancefloor may underpin these lived experiences. Moreover, cross-disciplinary literature on EDM culture situates EDM events as a source of collective effervescence (e.g. Garcia, 2020; Liebst, 2019; Olaveson, 2004) a profound feeling of unity and shared positive energy that may arise in communal activities (Durkheim, 1912). Garcia (2020) posits that collective effervescence may underpin notions of the 'vibe'; a colloquialism commonly used amongst participators in EDM culture that is iterated in subjective accounts of participation. The 'vibe' may be seen as a communal, positive energy that characterises an EDM event (Rill, 2006; Sommer, 2001; St John, 2008), and frequently accompanies accounts of profound embodied and emotional connection with the music (e.g. Fikentscher, 2000). Indeed, it may be the sustaining of the 'vibe' that creates a sense of connectedness and community between participants (St John, 2008). As such, it may be theorised that 'the vibe' and associated feelings of social connection may be related to participants' collective embodiment of EDM. Embodying the music via entrainment facilitated by the syncopated beat of EDM is an inherently pleasurable process. Witek (2017) suggests that syncopation underpins the structural intricacy of groove, creating rhythmic spaces that encourage the body to engage through entrainment. As the body fills these temporal gaps, the drive to complete the groove enhances the pleasure of participation and reinforces dance movement. This participatory pleasure may be expressed outwardly on the dancefloor through movement, which is then observed by other participators, and, as such, dance may be considered a mediator for embodied emotional expression (White & Egermann, 2021). Where the musical processes of EDM may serve to facilitate synchronous movement, it may be the recognition of moving in synchrony with others, and the emotional contagion experienced through the observation of pleasurable dance that, in turn, evokes powerful emotional responses within a group setting. Furthermore, the recognition of synchrony may also lead to feelings of *kama muta* (or 'moved by love'), a profound emotional state characterised by a sense of unity and sometimes accompanied by chills or tears (Fiske et al., 2019). A positive association between *kama muta* and social connection has previously been found in research on virtual concert settings (Swarbrick et al., 2021), however this phenomenon has not yet been explored in an EDM context. Overall, existing research suggests that embodied and emotional experiences with music, when shared among participants, may reinforce social bonding amongst a group (see Brown & Fredrickson, 2021; Fiske et al., 2019; Newson et al. 2021; Pizarro et al., 2021). Despite the potential for emotional and interpersonal synchrony to foster connectedness, the extent to which these experiences may be interrelated and contribute to social bonding in an EDM context is yet to be systematically examined. Though previous research has analysed group entrainment and interpersonal synchrony to music in a replica EDM setting (Solberg & Jensenius, 2017), and in a real-world disco event (Ellamil et al., 2016) relationships between emotional experiences, social bonding and movement have not been examined within a naturalistic, real-world EDM context. The current preliminary study builds upon previous research by trialling an experimental paradigm to investigate associations between these factors that may be utilised in an EDM context.

Aims

The overarching aims of the current study were to trial a methodological approach for the measurement of emotion, social bonding and movement on an EDM dancefloor and to test the efficacy of analysis pipelines for the assessment of interpersonal synchrony and entrainment. As such, the study was guided by the following exploratory research questions:

1. Can accelerometers be used to effectively measure the movement of dancers within a club-like environment?
2. Can accelerometer data be analysed effectively to measure both (a) rhythmic entrainment to the music and (b) interpersonal synchrony between a dancer and a group?
3. Do participants report strong emotional experiences following an EDM event as measured through self-reported experiences of *kama muta* and distributed, embodied pleasure?
4. Does self-reported social bonding with a group increase following engagement in an EDM event?
5. Can the degree to which a dancer is (a) rhythmically entrained to the music, and (b) interpersonally synchronised with the rest of the group, be effectively correlated with scores on self-report measures of emotional experience and social bonding?

Method

Participants

Volunteer sampling was used to recruit participants at the University of Leeds who had an interest in EDM, advertising on institutional mailing lists and within research groups. Five participants (two male, three female, aged 25-41) were recruited. Participants were provided with an information sheet and required to complete a consent form prior to scheduling their involvement in the study. The study received full institutional ethical approval (FAHCS ref. 1120).

Materials

Empatica E4 wristbands were used to measure movement using the 3-axis accelerometer function with a 32 Hz sampling rate. The accompanying *E4 Connect* software was used to upload sensor recordings and for initial inspection of data. A pre-event and post-event survey were created for participants to complete before and after the dance session. The pre-event survey included a social bonding index (SBI) adapted from Tarr et al. (2016), measuring each participant's degree of connectedness, likeability, similarity in personality and closeness with the participant group. The post-event survey included a repeated SBI in addition to a 3-item measure of emotional contagion (ECS) (Garrido & Macritchie, 2018), an 18-item perceived emotional synchrony scale (PESC) (Páez et al, 2018), the 24-item *kama muta* scale (KAMMUS-2) (Zickfeld et al., 2019) and a 7-item 'embodied pleasure' scale (EPS), a novel scale designed for this study to measure the degree to which participants experienced pleasure associated with musical embodiment for the duration of the event (cf. Garcia, 2005; Witek, 2017). Data on participants' preference for the music, their desire to dance, and perceived ecological validity of the replica club set-up was also collected in addition to demographic information. All scale items were measured on 5-point or 7-point Likert scales.

Figure 1. Participants on the dancefloor during the study.

Procedure

Participants completed the study in a performance studio at the university, adapted to mimic a club-environment. Inspired by a similar setup used by Solberg and Jensenius (2016), this featured a dancefloor space, dynamic lighting sequence, and multi-channel surround sound speaker system. Figure 1, below, shows the venue setup during the dance session. Participants first completed the pre-event survey before being fitted with *Empatica E4* wristbands. Participants then danced to a pre-recorded DJ mix for approximately 30 minutes. During this time, the main lighting was dimmed to create a dark, club-like environment and a dynamic lighting sequence was activated. Participants then completed the post-event survey to finish the study. Surveys were completed on participants' mobile devices on *Qualtrics* via a QR code. Anonymous participant ID codes were created to link survey responses to the wristband serial numbers assigned to each participant. All *Empatica E4* wristbands were synced with the internal clock of the researcher's laptop immediately prior to data collection. During the dance session, the laptop was set up to simultaneously screen record the ongoing timestamp of the DJ mix alongside the internal clock time, to use for later alignment of datasets.

Results

Accelerometer data pre-processing

Initial inspection of accelerometer data on *E4 Connect* showed all wristbands effectively recorded participants' movement for the duration of the dance session. Accelerometer data for each participant were then exported to Excel. As accelerometer recordings differed in duration between participants, all participants' acceleration datasets were truncated equally to represent an equivalent time-window that captured the beginning and end of the DJ mix. This was achieved by using using the UTC timestamp (converted from Unix) recorded by participants' wristbands at each timepoint (sample) and aligning it with the corresponding timestamp of the DJ mix. Truncated acceleration datasets were imported to MATLAB. The Euclidean norm (magnitude) was then calculated across each dataset using the formula $\sqrt{x^2 + y^2 + z^2}$ (Förstel et al., 2018). This represents overall acceleration at each timepoint, capturing the intensity of movement across all axes, at the loss of directional information with higher magnitude values (Katevas et al., 2015). Participants' datasets were then filtered using a Butterworth bandpass filter with a lower cutoff of 0.6 Hz and an upper cut-off of 5 Hz, a typical frequency range associated with meaningful human movement (Godfrey et al., 2008; Swarbrick et al., 2022).

Entrainment

Spectral analysis was used to assess the degree to which each participant was rhythmically entrained to the music for the duration of the DJ mix. A fast Fourier transform (FFT) was applied to each participant's acceleration data, converting it into the frequency domain (Hz). Power spectrums in which the complex magnitude of the FFT were plotted against frequency were created for each participant on MATLAB. The average BPM of the DJ mix was calculated by applying the *mirtempo* function from MIRtoolbox for MATLAB (Lartillot & Toiviainen, 2007) to the audio file of the mix (truncated to match the time-window of the acceleration datasets), giving an average tempo of 125.96 BPM. The half-time and double-time BPM values of the DJ mix were also calculated and these values, along with the normal-time BPM, were plotted on participants' power spectrums, as shown in Figure 2. Spikes in participants' acceleration amplitude predominantly corresponded with the BPM of the music at each metrical level, suggesting rhythmic entrainment.

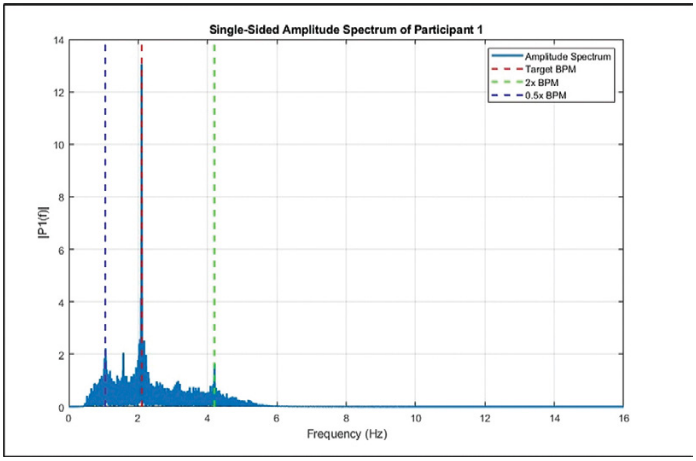

Figure 2. Average BPM of DJ mix at each metrical level plotted over the Fourier transformed single-sided amplitude spectrum for participant 1. Note. [P1(f)] represents the power of frequencies within the signal.

To calculate the degree to which participants were entrained for the duration of the mix, the trapezoidal numerical integration was used to analyse the relative power of the frequency corresponding to the average BPM of the DJ mix for each participant at each metrical level, with a tolerance window of ± 2.5%. This was computed on MATLAB using the *trapz* function and may be expressed as the following formula, where *a* represents the lower frequency limit, *b* the upper frequency limit and *f* the power spectrum of the given Fourier transformed signal:

$$Integral \approx \int_a^b f(x)dx$$

To compare entrainment between participants, the integrals calculated using the formula above were normalised. This was achieved by calculating the proportion of frequency power within the tolerance window relative to the overall frequency power in each signal. The integral of the whole frequency spectrum (0 Hz to 16 Hz) was computed for each participant using trapezoidal numerical integration. Each participant's integral values at each metrical level were then divided by their overall integral value to calculate the entrainment proportions. These values were multiplied by 100 to convert them to percentages, as displayed in Table 1. Total proportions of entrainment relative to overall signal power were low. This may be due to the narrow tolerance window used when calculating the integrals at the target BPM, and the compounding degree of spurious frequencies within the acceleration signals.

Table 1. Participants' proportionate entrainment (%) at each metrical level and summed total entrainment proportion (%) relative to overall frequency power.

Participant No.	% 1x	% 2x	% 5x	Total %
Participant 1	11	3	4	18
Participant 2	11	3	4	18
Participant 3	9	3	3	15
Participant 4	10	2	4	16
Participant 5	8	2	4	14

Quantity of motion

Quantity of motion (QoM) was analysed following procedures used in existing movement and live music research using accelerometers (cf.

Swarbrick et al., 2022). It must be noted that the pre-processing steps used in QoM analysis differ from those applied in entrainment analysis as specified earlier. Movement axes were not combined beforehand for this analysis as a Euclidean approach was executed as part of the initial QoM calculation on MATLAB. A Butterworth bandpass filter (0.6 – 5 Hz) was therefore applied to the accelerometer data on each movement axis for each participant prior to this analysis. A QoM time series was calculated for the duration of the DJ mix for each participant's accelerometer dataset. This was calculated by taking the absolute change of the accelerometer data at each time point to represent when participants were moving to the music using the formula $QoM\ \sqrt{(xt2 - xt1)^2 + (yt2 - yt1)^2 + (zt2 - zt1)^2}$ where t represents time ($t1$ and $t2$ represents two consecutive time points or samples). QoM data for each participant was smoothed using a Savitzky-Golay filter (order: 1, window: 299) (Swarbrick et al., 2022). Table 2 shows the mean quantity of motion (mQoM) for each participants' overall signal duration computed by calculating the mean of participant's QoM values at each time point. A notably high mQoM compared to the group can be seen for participant 1.

Table 2. Mean quantity of motion (mQoM) values for the overall DJ mix expressed in units of acceleration per time step (m/s²) and average degree of synchronisation (*Rho*) for each participant.

Participant No.	mQoM	*Rho*
Participant 1	720.86	.324
Participant 2	469.65	.373
Participant 3	495.04	.381
Participant 4	348.39	.367
Participant 5	421.70	.383

Group synchrony

Cluster phase analysis was used to measure how synchronised each participant was with the overall participant group. This was carried out following the guidelines of Richardson et al. (2012), using their Cluster Phase Analysis Toolbox provided for MATLAB. The phase time series for each participant's accelerometer signal was computed using a Hilbert transform. The average (cluster) phase time series was then computed by averaging the phase values for all participants at each time point. The relative phase for each participant was then calculated at each time point by subtracting the group's average (cluster) phase from each participant's individual phase time series. The relative phases over all time points for each participant were then summed for each time series and divided by the number of time points, giving the mean relative phase for each participant. The resulting degree of synchronisation value (*Rho*) indicates how consistently a participant's movement is synchronised with the group on a scale between 0 and 1. Higher *Rho* values indicate a greater degree of synchronisation with the group. The *Rho* for each participant is displayed in Table 2. The average of all mean relative phases of all participants at each time step was $M = .382$, representing the mean degree of overall group synchronisation. This suggests that the group had a relatively low degree of overall group synchrony. This may be due to individuals having unique dance styles (Marchiano & Martinez, 2018) which may be rhythmically synchronised with the music but may not be captured as synchronous behaviours between individuals by phase analysis.

Emotional experiences

In line with the exploratory research aims of the current study and small sample size, descriptive statistics are presented to illustrate results on Likert-scales of emotional experience. Total scores for the EPS, KAMMUS-2 and PESC scales were calculated for each participant by summing their scores across each scale's respective items. Reliability analysis was also conducted for each scale. Table 3 shows the mean scores, standard deviations, range and Cronbach's alpha value for each of these scales. It was hypothesised that participants would experience moderate to high levels of embodied pleasure, *kama muta* and perceived emotional synchrony during the dance session. A high mean total score on the EPS suggests that participants experienced strong feelings of embodied pleasure ($M = 37$, $SD = 6.33$). A relatively low mean total score on the KAMMUS-2 ($M = 61.60$, $SD = 12.44$), suggests that participants experienced low to moderate levels of *kama muta*. The mean value for total perceived emotional synchrony levels suggests this was experienced moderately ($M = 62.80$, $SD = 19.37$). These results partially support the hypothesis and suggest that embodied pleasure is a salient emotional experience within an EDM context. In addition, the highest mean rating to the ECS was in response to the item 'The response of other people in the audience amplified my own emotional response to the music' ($M = 5.40$), suggesting emotional contagion was present amongst the group.

Table 3. Descriptive statistics of variables measuring participants emotional experiences ($N = 5$).

Variables	EPS	KAMMUS-2	PESC
M	37.00	61.60	62.80
SD	6.33	12.44	19.37
Range	26-42	43-77	45-95
α	.866	.825	.965

Social bonding

The difference between participants' pre-event and post-event SBI scores was calculated. It was hypothesised that participants' levels of social bonding with the group would increase following the dance session. It was found that participants' mean social bonding scores increased from pre-event ($M = 12.40$, $SD = 2.70$) to post-event ($M = 15.40$, $SD = 3.29$), supporting the hypothesis. A Wilcoxon signed rank test showed that participants' overall increase in social bonding scores was significant ($Z = -2.041$, $p < 0.05$), though this is tenuous in the context of the small sample size. This lends tentative support to the hypothesis that dancing in a group at an EDM event promotes social bonding.

Music preference & ecological validity

All participants "somewhat liked" ($n = 2$), "liked" ($n = 2$) or "really liked" ($n = 1$) the style of music playing. All participants reported a desire to dance either "often" ($n = 3$) or "all of the time" ($n = 2$) suggesting the music had a high level of groove and was conducive to dance movement, as would be expected of EDM (Burger & Toivianien, 2020). All participants reported they either agreed ($n = 2$) or strongly agreed ($n = 3$) with the statement "I felt like I was able to dance how I would usually at a real-world dance music event (i.e., nightclub or festival)" and "somewhat agreed" ($n = 1$) or "agreed" ($n = 3$) that the music playing gave the impression there was a DJ in the room, with one participant stating they "neither agreed nor disagreed" with this statement. Most participants also "agreed" ($n = 2$) or "strongly agreed" ($n = 2$) that during the dance session they felt they were at a dance music venue. Only one participant "somewhat disagreed" with this statement. These results suggest that the musical stimuli and replica club set-up used were largely effective in approximating the feel of real-world EDM context.

Correlations

Scatterplots were created to inspect possible relationships between total scores on both (a) emotional experience scales and (b) SBI increase values (the difference between pre- and post-event SBI total) with entrainment, *Rho* and mQoM values. As shown in Figure 3 below, there was a positive trend indicated between SBI increase and entrainment value. However, this is tenuous given the small sample size employed in this preliminary study. Correlational analysis was not conducted due to the small sample, and future work would benefit from employing such analysis on a larger sample.

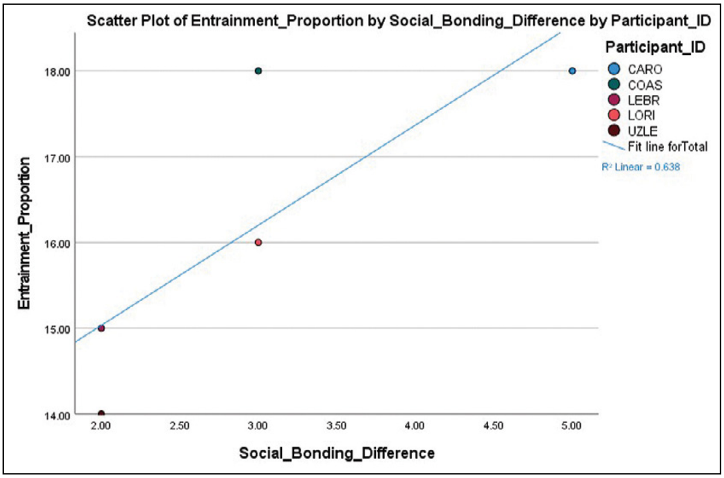

Figure 3. Entrainment proportion plotted against social bonding increase value (post-event) ($N = 5$).

Conclusion

The aim of the current preliminary study was to trial measures of interpersonal synchrony, entrainment, emotional experiences, and social bonding on a real-world dancefloor and test analysis methods for the assessment of relationships between these variables. Testing of three analysis pipelines for the assessment of interpersonal synchrony (QoM and cluster phase analysis) and entrainment (spectral analysis) using time series data yielded from wrist-worn accelerometers in a replica club setting achieved this preliminary aim. Initial findings indicate a possible relationship between entrainment and social bonding on the dancefloor and suggest that experiences of embodied pleasure and emotional contagion are salient. However, due to the limited sample size, and the lack of a control group, no conclusions should be drawn here regarding relationships between movement, emotional experiences, and social bonding. The experimental and data analysis procedures and associated MATLAB toolboxes developed here should subsequently be employed in further field studies with increased ecological validity and sample size to further examine these relationships. Planned follow-up studies by the authors aim to collect data in a true real-world EDM event using smartphone accelerometers and, additionally, examine the role of DJ behaviour (cf. Biehl, 2019). It may be fruitful in follow-up research to gather more contextual data on interaction behaviour between participants, and shared emotional responses to the music, via analysis of video recordings or through observational techniques. This research is warranted to develop our understanding of embodied and emotional experiences at EDM events and their role in facilitating social bonding.

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