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The Role of Synchrony in Expert Hip Hop Dance Competitions

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Abstract

Hip hop dance competitions have grown in popularity in recent years, but there is minimal research assessing the reliability of hip hop judging and whether certain elements of dance routines impact scoring more than others. Considering the aesthetic appeal of synchrony in dance, we investigated whether the winning group can be predicted by how objectively synchronized the dancers were, hypothesizing that the most synchronized routine will win. We held an in-person hip hop dance competition, with six groups of five experienced dancers wearing motion capture markers. Five paid expert judges determined the winner by assessing the routines on choreography, execution (including synchrony), and overall cohesion. Simultaneously, audience members provided their own scores. Synchrony was a significant predictor of scores for both judges and audience members. The judges were highly consistent in their scoring, with an intra-class correlation coefficient of 0.94. Audience members with hip hop dance training were significantly more likely to correctly predict the winning group compared to those without. The results emphasize the importance of synchrony in hip hop competition judging, but suggest that judges' expertise led them to incorporate additional important factors in their assessments.

INTRODUCTION

Hip hop dance is one of many street dance disciplines, with others including house, locking, popping, and breaking [1]. Like other street dance styles, hip hop can foster community by uniting dancers locally, nationally, and globally to participate in a wide range of events. As hip hop and street dance have risen in popularity from the streets of the Bronx all the way to the Summer 2024 Olympics, an increasing number of hip hop competitions are being held worldwide. However, scoring criteria are often not clearly defined and very little research has focused on judging reliability [2]. In the present study, we focus on how consistent professional judges and audience members are in judging hip hop competitions, with a particular interest in the importance of synchrony between dancers in determining ratings.

In the context of the aesthetic appeal of dance, movement synchrony refers to the ability of two or more dancers to execute movements together in both space and in time [3]. Several studies have found that synchrony influences the aesthetic enjoyment of watching dance performance. When people observed a 30-minute dance performance where movement synchrony between performers varied over time, functional magnetic resonance imaging (fMRI) revealed that movement synchrony among performers was the strongest predictor of neural similarity between observers, supporting theories that movement synchrony is a crucial component of aesthetics in dance performance [4]. In another study, observers of dyads moving either synchronously or asynchronously rated synchronous movement as more enjoyable [3]. Similarly, audiences rated pairs of dancers performing simple hip hop dance steps higher in aesthetic appeal when the dancers moved in synchrony compared to asynchrony [5]. This study also found that observing synchronous dance elicited greater pupil dilation compared to asynchronous dance [5]. In a contemporary dance performance presented to four different audiences, where movement synchrony was manipulated to vary over the course of the choreography, movement synchrony was a significant

predictor of both heart rate and continuous enjoyment ratings of the audience [6]. However, some audience members showed no relationship between synchrony and enjoyment ratings, or even a reverse relationship, suggesting factors other than performers' dynamic movement synchrony influenced audience enjoyment [6].

The appeal of synchrony across many dance and musical practices [5, 6] may relate to the general finding that moving in synchrony with other people, that is, coordinating movements in time, has been shown to increase trust, cooperation, empathy, and positive associations within groups [7–10], even promoting prosocial behaviour in infants [11–13]. From a physiological perspective, dancing in synchrony with others leads to increased pain thresholds, a commonly-used proxy for increased endorphin release [14]. Increased endorphin release is found both in synchronous activity with higher exertion, as well as shared musical experiences, both of which occur when people dance together [15]. Generalizing from participation in synchrony to *observation* of synchrony, the coalition-signaling hypothesis states that synchronized music-dance performances communicate group cohesion, signaling to observers they can form a cooperative alliance [5, 6, 16]. This hypothesis is supported by research showing observers expect synchronous dyads to affiliate more and work better together than asynchronous dyads [17]. In other words, synchrony in dance may signal group cohesion and cooperation among the dancers [8] and create an environment of social bonding that includes the audience.

Despite findings on preference for synchrony in dance performance, it remains unclear how large a role it plays in hip hop dance competitions, and whether preference for synchrony interacts with other factors. For example, cultural familiarity with a dance style appears to play a role in the preference for synchrony in dance [18]. Hip hop was originally performed at parties and battles [19]. One study found that dance battle competitors tended to synchronize in anti-phase with one another [20], but it is unclear what impact anti-phase synchrony has on observers. Further, as hip hop was historically often improvised, synchrony between dancers may not have been a very important factor considered by judges choosing winners of competitions or battles during its early development. However, as hip hop dance has become more mainstream, commercialized, presented to wider audiences, integrated with other styles of dance, and more planned and choreographed, synchrony may have become more important, and therefore more heavily weighted during judging and audience appreciation.

Although there is evidence supporting a preference for synchrony in the observation of dance performance, effects of the experience and expertise of the observers have been less studied. Research suggests dance expertise leads to increased perceptual efficiency; when expert and novice observers watched a contemporary dance film, the expert dancers had significantly faster saccades and shorter eye fixations for dance movements and configurations [21], indicating dance expertise enhances visual processing speed and the ability to anticipate and quickly process choreographic movements. In general, dancers create stronger mental representations of observed dance movements than novices, as reflected by stronger within-brain theta-band synchrony in electroencephalography (EEG) recordings while observing dance, whether from videos [22] or live performances [23]. Stronger theta-band

synchrony is associated with memory and multisensory processing [24, 25], as well as shifting spatial attention [26]. Further, fMRI studies showed higher neural similarity between the brains of trained ballroom dancers than between the brains of novices when watching dance performance videos [27], and higher neural similarity between the choreographer of a contemporary dance and trained versus novice observers [4]. While the studies reviewed above suggest expert and novice dancers differ in their neural responses to dance, few studies have examined whether their judgements are influenced by the same or different factors. Novice observers have been shown to prefer dance routines with symmetrical movement, continuous movement transitions, body postures that maximize spatial symmetry, higher movement amplitudes, faster turning velocities, and movements that involve the entire body such as jumps [28–31], but it is not clear whether they weight these factors similarly to expert dancers or, indeed, if expert dancers are consistent among themselves in their preferences.

Within dance competition judging, little research has investigated how consistent judges are in their ratings, the factors that influence their ratings, or how to implement objective judging measures. One study examined past score sheets of hip hop dance competitions held in Japan between 2014 and 2019 to determine judges' consistency and reliability [2]. Of the categories (technical quality, synchronization, impression, creativity, expression and interpretation), technical quality showed the highest reliability, and impression (whether the performance evoked emotional responses from audience) the poorest. Consistency scores were variable, ranging from fair to excellent across different categories. Synchronization showed good reliability but only moderate consistency. However, as this study only investigated past competitions, the authors were not able to compare any of the findings to objective measures of the performance [2].

The present study aimed to investigate: (1) the importance of movement synchrony, measured objectively using motion capture, in evaluation of hip hop dance quality, (2) the consistency of expert judges' scoring, including subjective synchrony scores, and (3) the role of dance experience in judgements of audience members during a high-level hip hop dance competition. We hosted an in-person hip hop competition in the McMaster LIVELab and collected motion capture data of the dancers during their performances. The judges determined the winner of the competition using a provided set of criteria, and audience members provided their own ratings of the performances. We hypothesized that given its aesthetic appeal, motion capture synchrony of the dancers would be a strong predictor of the competition winner, such that the routine with the highest level of synchronization would win the competition. We also predicted that audience members with hip hop dance training would be more similar to the judges in their scoring compared to non-hip hop trained audience members.

METHODS

Participants

Participants included competing dancer groups (6 groups of 5 dancers for a total n = 30), audience members (n = 74), and judges (n = 5). Dancers and audience members were recruited via public social

media posts. Judges were paid and selected based on extensive hip hop dance backgrounds and judging expertise. The five judges ranged in age from 28-39 years (*M* = 30.8, *SD* = 4.9). To compete, choreographers had to submit a sample piece of choreography and be approved by experimenters to ensure they had the requisite dance experience. All dancers paid a $10 registration fee. Competing dancers ranged from ages 16-27 years (*M* = 20.7, *SD* = 2.6). Audience members bought tickets and were invited to participate. They ranged from ages 17-56 years (*M* = 31, *SD* = 12.2). Prior to the competition, all participants (competing dancers, judges, and audience members) completed consent forms and demographic surveys, which included questions about their music and dance experience. For compensation, the winning group of the dance competition was given the dancer registration fees, totalling $300. This study was conducted in accordance with the McMaster Research Ethics Board (MREB #1975) and informed consent was obtained from all participants.

Stimuli

Each dance group provided their own musical selections, which were presented through the Meyer Constellation speaker system in the LIVELab. The average amplitude levels were matched across group. For consistency, simple white stage lighting was used during all competing performances.

Procedure

Each dancer could only compete in one group. Each group performed one routine between 2:20 - 2:40 min in length that contained only one song. To facilitate synchrony analyses, each routine was required to have a minimum of 15-20 seconds of choreography in which all dancers performed identical movements, including no level changes, formation changes, or differences in direction of movement. Competing groups chose their own costumes. Prior to the competition, dancers were sent an information packet containing the rules and regulations of the competition, along with a schedule for the competition day and the judges' score sheet (Table 1). Performance order was random. The choreographer(s) of each group choreographed their own dance routine and rehearsed it with their group prior to the competition day.

All competing groups had a 10-min technical run on the LIVELab stage in the afternoon of the competition to acclimatize to the motion capture markers. Only LIVELab staff and experimenters were permitted in the theatre at the time of technical runs. Motion capture was collected during the technical runs and the competition, but only the latter was analyzed.

The evening competition began with an emcee explaining to the audience how the research study would integrate into the competition. Each competing group performed once. The judges were given time to fill out their score sheets after each performance (Judge Score 1). All competing groups performed before intermission, at which point each judge was allowed to independently adjust their scores (Judge Score 2). Judges were then allowed to discuss amongst themselves the merits of the performances before providing their final scores (Judge Score 3), while the audience watched a showcase of three non-competing teams. Finally, the 1st and 2nd place winners were announced based on the judges' final

scores. All winning groups were presented with a certificate, and the first-place winner was awarded the $300 prize.

Audience participants were recruited on site from those who purchased tickets for the event. They also rated the performances after each routine according to a simplified rating sheet (Audience Ratings). Post-performance questionnaires were given to the performers after their own group's performance (Dancer Post-Performance Questionnaire).

Data Collection

The competition took place at McMaster's LIVELab research-based performance theatre in November 2023. There were 106 seats, with five reserved for the judges. Stage dimensions were adjusted to 132 x 254 inches by tape, to assure the movements of the dancers were fully captured by the motion capture system.

i. Motion Capture

The dancers' movements were tracked using the Qualisys motion capture system with 13 cameras at a sample rate of 100 samples per second. Dancers wore ankle bands and wrist bands containing one marker each, and a headband with two markers (six markers in total per dancer). The head markers were averaged together for data analysis. Only data during the performances were analyzed.

ii. Judges' Evaluations

Judges evaluated the performances using a score sheet created by the experimenters (Table 1), based on commonly used criteria at competitions [2]. The three main criteria categories were *Choreography* (with 2 subsections), *Execution* (3 subsections), and *Overall Cohesion*. Experimenters discussed the score sheet with the judges prior to the start of the competition. Each judge's overall score was the sum of the subsection scores, and each group's final score was calculated as the mean of the five judges' overall scores. Dancers were provided with copies of their own score sheet after the competition. Judges were also asked to provide their own suggested weights for each section. These weights were not used for the calculation of the top scoring group.

iii. Audience Ratings

After each performance, audience participants rated two questions on a scale of 1 to 10: 1) "Overall, what score would you give the performance?" and 2) "How well do you know the dancers in this piece?". After all six performances, they were asked to provide a ranking for first, second, and third place: "Please rank who you believe should win the top three places overall. This ranking does not need to line up exactly with your scores." Audience ratings had no influence in determining the competition winner.

iv. Demographics Questionnaire

All participants filled out a demographics questionnaire including questions on their dance and music background prior to the beginning of the competition.

v. Video and Audio Recordings

Performances were recorded using a Sony PXW-Z90V Version 2.01 camera to serve as a reference for cleaning the motion capture data and to investigate the intensity of audience cheering.

vi. Dancer Post-performance Questionnaire

The post-performance questionnaire asked the dancers to rate the following aspects of their routine, each out of 10. *Overall Performance*: “How well did you feel your performance went overall?”; *Synchrony*: “How synchronized did you feel your performance was?”; *Complexity*: “How complex did you feel the choreography of this dance piece was?”; *Creativity*: “How creative did you feel the choreography of this dance piece was?”; and *Execution*: “How well do you think your group executed the dance?”.

Table 1 Judges Score Sheet

Category	Subsection	Description	Comments	Score[1]
Choreography	Complexity	Difficulty		/20
		Musicality of choreography		
		Staging/transitions		
	Creativity	Creativity		/20
		Originality		
Execution	Technique	Technique/skill		/10
	Timing	Musicality of execution		/15
		Synchronization		
		Cleanliness		
	Stage Presence	Stage presence		/15
		Facials		
		Expression		
Overall Cohesion		Costume		/20
		Music		
		Overall flow of set		
Total				/100

[1]Judges were provided three columns for each sub-score: (1) immediately after watching the performance, (2) adjusted score after seeing all competing groups, and (3) adjusted score after discussion with other judges. Score 3 was used to determine the winner of the competition.

Data Preprocessing

i. Intra-Class Correlation Coefficients (ICC)

To assess the reliability of ratings provided by judges and audience members, Intraclass Correlation Coefficients (ICC) were calculated using the ICC(3,k) model. This model is appropriate for situations where the same fixed set of raters evaluates all subjects. A two-way mixed-effects model was used where rater effects were fixed, and the reliability was based on the mean ratings. The ICC(3,k) provides an estimate of the consistency of ratings, and was calculated for judges as well as audience members.

ii. Motion Capture Synchrony

For each marker, missing data was interpolated using linear interpolation for sections of time less than three seconds. An average of 5.4% of the data included in the analysis was interpolated (*SD* = 2.1% across groups). Sections with more than three seconds of missing data were not included in the analysis for that marker. An average of 1.7% of the data was not included (*SD* = 2.8% across groups). Spline smoothing was applied to each coordinate axis (X, Y, Z) of the position data before calculating the magnitude of velocity as the sum of the absolute value of each coordinate axis. Velocity magnitude was normalized across time for each marker within a participant. Sections of the routines were identified as identical movement if all dancers were performing the same movement at the same time (for at least three consecutive seconds), as determined by inspection of the videos by the experimenters. The total amount of identical movement time ranged from 41.6 s to 79.4 s (*M* = 63.6 s, *SD* = 15.1) across groups; the number of separate sections of identical movement ranged from 7-9 across groups. Synchrony was calculated as an average of the Pearson's correlation coefficients (lag = 0) of the velocities between each pair of dancers. To equate the amount of data analyzed across groups, a nested bootstrap procedure was used such that, for each identical movement section, 300 data points (the minimum number of data points in a section of identical movement) were randomly selected to calculate motion capture synchrony [32]. This procedure was repeated with 1000 resamples based on bootstrapping guidelines [33]. The synchrony of each section of identical movement was estimated as the average of the 1000 resamples. Synchrony was calculated separately for the head, wrist, and ankle markers between each pair of dancers (averaged across all possible pairs of dancers) for each section of identical movement within each group.

iii. Intensity of Audience Cheering

Music pieces were matched in intensity prior to the competition. Thus, differences in sound intensity during the performances largely reflected differences in the intensity of audience cheering. Average intensity was analyzed from the beginning of the music to the time at which the audience naturally stopped cheering (*M* = 10.08 s, *SD* = 1.26 s of cheering after music ended). The two stereo channels of the audio recordings were averaged together, and the intensity (volume) of each performance was calculated as the root mean square (RMS) amplitude.

RESULTS

Demographics

Demographic information for the dancers, audience members and expert judges is summarized in Table 2.

Competing Dancers

Competing dancers (n = 30) had 2-21 years of dance training experience (*M* = 9.48, *SD* = 6.8). A 1x6 analysis of variance (ANOVA) with group as a factor found no significant differences between groups for

years of dance training ($F(5,22) = 1.21$, $p = .335$). Music training experience ranged from 0-16 years of experience ($M = 3.89$, $SD = 4.8$), and a 1x6 ANOVA with group as a factor found no significant differences between groups ($F(5,22) = 0.56$, $p = .728$). Of the dancers, three identified as Black, four as White, fourteen as Asian, five as South Asian, one as First Nations, two as Latina, and one as mixed.

Audience Members

Audience members (n = 74) ranged from 0-38 years of dance training ($M = 5.6$, $SD = 7.48$). There were 32 hip hop dancers (HH), 15 non-hip hop dancers (NH) who indicated training in a dance style other than hip hop (or street dance), and 27 non-dancers (ND). The music training of the audience ranged from 0-15 years of experience ($M = 4.8$, $SD = 4.52$). Of the audience participants, 42 people identified as Asian, 6 as Black, 2 as Latina, 4 as mixed/biracial, 16 as White, and 4 participants did not report their ethnicity.

Judges

The five judges' years of training in hip hop and other street dance styles (including but not limited to popping, locking, and breaking) ranged from 9-24 years ($M = 17.0$, $SD = 5.6$). The judges had a range of 1-7 years of music training ($M = 3.5$, $SD = 3.0$). Two judges identified as Filipino, two as Black, and one as South Korean.

Table 2 *Demographics for all participants*

	Dancers	Judges	Audience
Sample Size	30	5	74
Female:Male:NB[1]	26:4:0	2:3:0	49:21:3
Age	20.7 ± 2.6	32.6 ± 6.3	31.0 ± 12.2
Years of Dance Training	9.48 ± 6.8	17.0 ± 5.6	5.6 ± 7.5
Years of Music Training	3.89 ± 4.8	3.5 ± 3.0	4.8 ± 4.5

[1]NB = non-binary.

Overall Scores and Questionnaire Responses

Judges Scores

The winner of the competition as assessed by the judges' scores (Fig. 1A-C) had the highest overall mean score of 86.80 ($SD = 9.47$) out of 100. Judges demonstrated high levels of consistency across competing groups, with an ICC of 0.94 (95% CI[0.845, 0.99], $p < .001$). A breakdown for each scoring subsection can be found in Table 3 and supplementary material (Fig. S1) based on their final scores. On average, judges changed their total scores by 1.75 points ($SD = 1.65$) at the first adjustment period and

0.63 points (*SD* = 0.79) at the second adjustment period. Changes are presented visually in supplementary material (Fig. S2). Their scoring consistency was high even with the initial scores provided immediately after each performance, ICC = 0.90 (95% CI[0.73, 0.98], $p < .001$).

ICC was calculated for scores for each subsection using the final score (Score 3). Under Choreography, Complexity showed an ICC of 0.88 (95% CI[0.68, 0.97], p < .001) and Creativity an ICC of 0.90 (95% CI[0.72, 0.98], p < .001). In the Execution section, Technique showed an ICC of 0.81 (95% CI[0.49, 0.96], p = .003), Timing an ICC of 0.86 (95% CI[0.63, 0.97], p < .001), and Stage Presence an ICC of 0.80 (95% CI[0.46, 0.96], p = .004). Finally, Overall Cohesion had an ICC of 0.92 (95% CI[0.78, 0.98], p < .001).

Judges' suggested weights for the subsections of the score sheet indicated fewer points be allocated to the complexity of choreography (M_{points} = 18.6 ± 0.9), creativity of choreography (M_{points} = 16.6 ± 0.9), and overall cohesion (M_{points} = 14 ± 1.7) and more points allocated to technique (M_{points} = 16.1 ± 0.6), timing (M_{points} = 18.1 ± 1.6), and stage presence (M_{points} = 16.6 ± 3.3). In recalculating the scores with the mean suggested weights, the order of groups' final scores do not change ($M_{Group\ 1}$ = 77.5, $M_{Group\ 2}$ = 65.2, $M_{Group\ 3}$ = 73.4, $M_{Group\ 4}$ = 86.7, $M_{Group\ 5}$ = 73.2, $M_{Group\ 6}$ = 62.9). Mean suggested weights are shown compared to actual weights in supplementary material (Fig. S3).

Table 3 Means and Standard Deviations (SD) of Judges and Audience Scores

			Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Judges[1]	**Total (/100)**	**Mean**	**78.00**	**65.60**	**74.00**	**86.80**	**73.70**	**64.00**
		SD	**10.22**	**7.13**	**14.00**	**9.47**	**4.44**	**11.77**
	Complexity (/20)	Mean	15.60	12.80	14.40	17.00	15.10	13.40
		SD	2.61	2.05	3.36	2.35	2.25	3.29
	Creativity (/20)	Mean	15.20	12.40	14.20	16.40	15.00	12.60
		SD	3.03	2.61	3.11	2.70	1.58	3.44
	Technique (/10)	Mean	7.40	6.00	6.20	8.20	7.40	5.20
		SD	0.55	1.73	2.39	1.10	0.89	1.64
	Synchrony (/15)	Mean	11.80	9.80	11.60	13.80	10.00	9.20
		SD	1.10	1.48	2.30	0.84	1.87	1.10
	Stage Presence (/15)	Mean	11.40	10.60	12.20	13.40	10.80	10.20
		SD	2.07	1.52	1.30	1.14	0.84	1.92
	Cohesion (/20)	Mean	16.60	14.00	15.40	18.00	15.40	13.20
		SD	2.88	1.87	2.88	2.00	1.67	2.05
Audience[2]	**Score (/10)**	**Mean**	**8.24**	**6.85**	**9.12**	**8.91**	**8.45**	**6.96**
		SD	**1.05**	**1.07**	**0.71**	**0.95**	**1.26**	**1.23**
	Familiarity (/10)	Mean	2.34	2.91	2.74	2.39	3.01	2.34
		SD	2.58	3.03	2.69	2.92	3.16	2.65
	HH Score (/10)	Mean	8.11	6.78	9.02	9.07	7.98	6.46
		SD	1.26	1.10	0.75	0.88	1.15	1.15
	NH Score (/10)	Mean	8.12	6.33	9.27	8.77	8.98	7.20
		SD	0.75	1.11	0.68	0.96	1.00	1.15
	ND Score (/10)	Mean	8.46	7.23	9.15	8.80	8.70	7.41
		SD	0.89	0.90	0.70	1.02	1.35	1.19

[1]Judges (averaged across the five judges) scores reflect responses from their score sheets. Total scores are the sum of all subsections. Only their final scores are reported.

[2]Audience (averaged across the 74 audience members) scores reflect responses from their score sheets. Scores are then broken down by dance training of the audience members. HH = hip hop trained

(n = 32), NH = non-hip hop trained (n = 15), ND = non-dancer (n = 27).

Audience Scores

Fig. 1D shows audience members' overall mean scores across competing groups, with a highest overall mean score of 9.12 (*SD* = 0.71) out of 10. All audience scores are summarized in Table 3. It can be noted that audience members rated a different group as having the top score than the judges. Audience members' familiarity with dancers did not differ significantly across groups ($F(5,444) = 0.84$, $p = .523$). Overall, audience members showed a moderate consistency in scoring across pieces with an ICC of 0.67 (95% CI[0.57, 0.76], $p < .001$). To investigate the impact of hip hop training on these scores, ICCs were calculated separately for the three different audience groups. The hip hop trained group showed an ICC of 0.74 (95% CI[0.60, 0.84, $p < .001$), the non-hip hop trained group an ICC of 0.73 (95% CI[0.50, 0.88], $p < .001$), and the non-dancer group an ICC of 0.53 (95% CI[0.26, 0.73], $p = .003$).

The overall audience scores (averaged across audience members) were then correlated to each subsection of the judges' score sheets (averaged across judges) to investigate which subsections of the judges' scoring related most strongly to the audience overall scores (Table 4). Note that these presented p-values are not corrected for multiple comparisons and should be considered as exploratory. After correcting for multiple comparisons using Bonferroni correction, no correlations reached significance ($p > .05$).

Table 4 *Pearson's Correlations between Judges' Subsection Scores and Audience Total Scores*

Judges' Subsection Score	Audience Total Score	
	Coefficient[1]	P-Value[2]
Complexity	.79	.060
Creativity	.85	.031
Technique	.70	.122
Timing	.76	.080
Stage Presence	.80	.055
Overall Cohesion	.80	.058

[1]Correlations were performed between judges' total scores (averaged across the five judges) and audience total scores (averaged across the 74 audience members).

[2]P-Values are not corrected for multiple comparisons. Degrees of freedom = 4 for all tests, representing the six groups included in the analysis.

Finally, audience scores were correlated with the intensity of audience cheering (RMS) for each competing group to investigate whether there was a relationship between how loud the audience cheered for each piece with how highly they scored them (Fig. 1E). Results show a moderate positive correlation, though it did not reach significance, r(4) = 0.53, p = .279.

Dancer Post-Performance Questionnaires

All post-performance questionnaire results are summarized in Table 5, averaged across all members of the group. Statistical correlations were not conducted between the dancers' responses with the judges scores, as the judges saw all groups perform whereas the dancers did not see other performances and therefore did not complete their responses in relation to other groups.

Table 5 Mean and standard deviations (SD) of Dancers' Ratings of their own performances

		Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Overall	**Mean**	**9.00**	**6.80**	**9.00**	**8.20**	**9.00**	**7.80**
	SD	**0.00**	**0.84**	**1.41**	**0.45**	**1.22**	**1.92**
Complexity	Mean	8.80	5.80	8.20	9.40	6.00	8.60
	SD	0.84	2.17	0.84	0.55	2.55	0.89
Creativity	Mean	9.20	6.20	8.80	9.20	7.00	8.20
	SD	0.84	1.92	1.10	1.10	2.00	0.84
Synchrony	Mean	9.00	5.80	9.00	7.00	8.60	7.00
	SD	0.00	1.48	1.22	1.22	1.14	2.00
Execution	Mean	9.00	7.00	9.00	8.20	9.00	8.00
	SD	0.71	1.22	0.71	0.84	1.00	1.58

Motion Capture Synchrony of Competing Groups

Mean motion capture synchrony scores of the competing groups were calculated only during sections of time where dancers were performing identical movements. A linear regression analysis was conducted to predict judges' overall scores based on motion capture synchrony, length of identical movement section (in s), and the interactions between markers and motion capture synchrony. The model accounted for 10.3% of the variance in judge scores, R^2 = .103, adjusted R^2 = .064, $F(10,229) = 2.62$, p = .005. The intercept was significant, β = 71.06, SE = 1.97, $t(229) = 36.08$, $p < .001$. Among the main effects, motion capture synchrony was a significant predictor of judge scores, β = 11.48, SE = 3.50, $t(229) = 3.28$, p = .001. Length of identical movement section also significantly predicted judge scores, β = −0.40, SE = 0.10, $t(229) = -4.06$, $p < .001$, indicating that longer identical movement sections were

associated with lower overall scores. None of the interactions between motion capture synchrony and marker reached significance.

A similar linear regression investigated the prediction of audience scores based on motion capture synchrony, length of identical movement section (in s), and the interactions between markers and motion capture synchrony. The model accounted for 11.6% of the variance in audience scores, R^2 = .116, adjusted R^2 = .08, $F(10,229) = 3.02$, $p = .001$. The intercept was significant, β = 7.66, SE = 0.22, $t(229) = 35.22$, $p < .001$. Among the main effects, motion capture synchrony was a significant predictor of audience scores, β = 1.50, SE = 0.39, $t(229) = 3.89$, $p < .001$. Length of identical movement section also significantly predicted audience scores, β = −0.05, SE = 0.01, $t(229) = -4.11$, $p < .001$, indicating that longer identical movement sections were associated with lower scores. None of the interactions between motion capture synchrony and marker reached significance.

As shown in Fig. 1, the group with the highest motion capture synchrony (averaged across markers), Group 3 (Fig. 1F), corresponded with the audience's highest scoring group (Fig 1D), but not the judges' highest score (Fig. 1C). Spearman's rank correlation coefficients show a smaller association between motion capture synchrony (averaged across markers) and judges' scores (averaged across judges), $r(4) = 0.66$, $p = .175$, compared to the association between motion capture synchrony and audience's scores (averaged across audience members), $r(4) = 0.83$, $p = .058$.

To investigate which factors of the judges' scoring were related to synchrony, motion capture synchrony (averaged across markers) was correlated with the individual subsections of the judges score sheet (averaged across judges). Results showed the strongest correlations with motion capture synchrony were judges' ratings of Timing ($r = .65$) and Stage Presence ($r = .71$). The weakest relation was between motion capture synchrony and ratings of Technique ($r = .12$). All Pearson's correlations are summarized in Table 6.

Table 6 *Pearson's Correlations between Judges' Subsection Scores and Motion Capture Synchrony*

Judges' Subsection Scores	Motion Capture Synchrony	
	Coefficient[1]	P-Value[2]
Complexity	.45	.370
Creativity	.41	.420
Technique	.12	.815
Timing	.65	.160
Stage Presence	.71	.116
Overall Cohesion	.44	.378

[1]Correlations were performed between judges' subsection scores (averaged across the five judges) and motion capture synchrony (averaged across markers).

[2]P-Values are not corrected for multiple comparisons. Degrees of freedom = 4 for all tests, representing the six groups included in the analysis.

Audience Similarity to Judges

To investigate the influence of hip hop dance training on the audience's ability to score the dances, similarity was evaluated as the Pearson's correlation coefficient between each audience member's overall score with the judges' final scores (averaged across judges). All Pearson correlation coefficient calculations had four degrees of freedom, representing the six groups included in the measure. To investigate the effect of dance experience, similarity scores were then separated by the three groups of dance training: hip hop (HH), non-hip hop (NH), and no dance training (ND). Results are summarized in Fig. 2A. A 1x3 ANOVA was conducted on similarity (Pearson's coefficients) with the between-subject factor of dance training (HH, NH, and ND). Results showed a significant effect of dance training ($F(2, 71) = 5.55$, $p = .006$). Post-hoc Welch's t-tests (Bonferroni corrected) between training groups found that hip hop dancers were significantly more similar to judges than non-dancers ($t(36.9) = 2.95$, $p = .005$, $p_{bonf} = .016$). Hip hop dancers were more similar to judges than non-hip hop dancers, but this did not reach significance after correcting for multiple comparisons ($t(30.1) = 2.14$, $p = .040$, $p_{bonf} = .121$). Non-hip hop dancers and non-dancers did not differ significantly ($t(39) = 1.37$, $p = 1.78$, $p_{bonf} = .534$).

Fig. 2B shows the percentage of audience members who correctly predicted the judge's choice of winner, separated by dance training, based on audience members' final choice of winner after having seen all of the performances. The hip hop dance trained group had the highest proportion of participants (30.3%) who correctly predicted the winner, while 13.3% of non-hip hop dancers and 11.5% of non-dancers correctly predicted the winner, both below chance level. A chi-square test examining the effect of dance training on the proportion of participants who predicted the correct winner revealed a significant effect of dance training, $\chi^2(2) = 371.76$, $p < .001$.

DISCUSSION

The present study was the first to investigate an in-person, high-level hip hop dance competition using multiple simultaneous modes of data collection. This experiment was novel in its methodological design, ecological validity, and use of motion capture during a real hip hop dance competition with expert-level dancers and professional judges. The results showed that an objective measure of synchrony via motion capture analyses was a significant predictor of scores from both the highly experienced judges as well as audience members. At the same time, the first-place winning group as assessed by the judges was not the one with highest motion capture synchrony. However, objective synchrony may play a stronger role in the audience member's impression of the dance performances, as the highest overall score aligned with the most objectively synchronized group. Audience members with

hip hop dance training were twice as likely as non-hip hop trained participants to choose the same winning group as the judges. Further, the dance training of the audience members was a significant factor in how similar their scores were overall to those of the judges. Finally, judges' scores were highly correlated, suggesting that they used similar metrics for evaluation.

Judges are Highly Consistent in their Scoring Across Groups

Although the judges were not identical in their scoring and differed in the range of scores used, they were highly consistent in their relative scoring across groups. This remained true for their initial scores, first adjustment scores, and final adjustment scores. In fact, most of the scoring adjustment occurred at the first adjustment period, at which point judges had seen all the groups but not each other's scores.

The consistency of judges' scores across subsections differed from the reliability scores found in a previous study [2]. In our study, technique had the lowest consistency (ICC = 0.81), and overall cohesion the highest (ICC = 0.92). The previous study found technique to be the most reliably judged subsection and overall impression to be lower [2]. Thus, how subsections are described to judges, and the context of the competition may affect how reliably certain factors are judged.

To gain insight into the judges' expert opinions on the provided score sheets, they were asked to give their preferred weighting for each subsection. On average, the judges indicated they would put more weight (points allocated) for execution, which included more points for technique, timing, and stage presence. They indicated they would allocate fewer points for choreography (creativity and complexity), as well as overall cohesion. This helps inform the design of score sheets for future competitions and calls for a greater emphasis on execution of dance performance in competition settings. It should be noted that the order of the groups' scores did not change when recalculated using these suggested weights.

Audience Members Chose a Different Winner than Judges

Interestingly, audience members' highest mean score did not align with the highest mean score from the judges, suggesting audience members may have weighted (valued) the factors differently compared to judges. Understanding street dance technique, the intricacies of timing and musicality, and the complexity of movement and choreography are likely to be scored more appropriately by judges with high levels of expertise. It is also important to note that the audience members scored the pieces on an overall scale of 1-10, while the judges scored individual subsections, which likely enhanced their ability to take multiple factors into account.

Another explanation for why the judges and audience members evaluated the competing routines differently could relate to differences in intentions. Audience members likely came to enjoy watching the performances, and therefore were influenced more by the aesthetic appeal of synchrony. The judges were there to evaluate the performances and determine a winner. As a result, they may have been less

influenced by personal enjoyment and more focussed on the subsections of the score sheets to ensure fairness.

What Factors Might be Influencing Audience's Members Scoring?

While the judges were provided a detailed score sheet with six different subsections, audience members were asked simply to provide a score from 1-10. Correlations between the audience members' overall score with the subsections of the judges' scores can provide insight into what factors may be related to the audience's perception of the performances. Higher correlation coefficients were found between audience members' scores and judges' scores for creativity of the choreography, overall cohesion of the performance, and stage presence. Compared to more technical aspects of the performances, these may be more subjective, require less training to evaluate, and relate more to overall enjoyment of the performance than objective quality.

The Role of Synchrony

Motion capture synchrony was a significant predictor of scores from both judges and audience members, emphasizing the importance of movement synchrony in dance observation, aligning with research showing the aesthetic appeal of synchrony in dance performance [3–6]. However, contrary to our hypothesis, the winning routine of the competition did not have the highest level of objective synchronization. Interestingly, the audience members rated the objectively most synchronized group highest, suggesting the audience may have valued routines higher in synchrony more than the judges. Spearman's rank correlations showed higher coefficients for motion capture synchrony to the audience rankings compared to the judges. Though these correlations did not reach significance, likely due to low power from having only six dance groups, they indicate a complex relationship between synchrony and scoring, since the routines' synchronization levels did not predict the exact rankings for either the audience or the judges. The length of the sections containing identical movement in all five dancers varied across groups, and was also a significant predictor of judges and audience scores, such that choreographies with longer identical sections had lower scores. This may be because with longer sections of the same movement, observers are more easily able to identify lower amounts of synchrony. It may also reflect less interesting or creative choreography if the observers felt the dancers were doing the same movement for too long.

It is also possible that our objective measure of synchrony did not capture all aspects of what makes a performance be perceived as synchronized. One limitation with our approach is that the entire dance was not included in the analysis of motion capture synchrony, as we only analyzed the sections when the dancers were performing identical movement. The observers (both judges and audience members) of the performance, on the other hand, would have considering the entire performances in their scoring. A second possible limitation is that we calculated motion capture synchrony using only velocity. Velocity takes into account movement timing information but not necessarily positional information that might also influence synchrony perception. As synchrony research strives towards accounting for both timing and positional synchrony [34–36], incorporating these features in synchrony measures should be a focus

of future experimental designs. Additional research on what objective measures of synchrony best capture viewers' perceptions of synchrony during highly complex movement such as hip hop dance would benefit the fields of dance, movement, and synchrony research.

The objective measure of motion capture synchrony was not only strong correlated with judges' ratings of how synchronized the dancers' movements were, but stage presence was also strongly correlated with motion capture synchrony. This may reflect an interaction between stage presence and timing, such that expression and energy of a dance performance can be appreciated more, and therefore scored higher, when the movements are also synchronized. Interestingly, the technique subsection was the least related to synchrony, indicating that hip hop technique comprises important factors other than synchrony.

Audiences Make Their Voices Heard in Hip Hop Dance

The audience has been historically very important in hip hop culture. The winners of dance battles were typically decided by the cheering level of the audience, which likely caused the audience to be more engaged and vocal while watching competitions [2,37]. Although it is less common now for audience members to be the sole deciding factor, this history likely contributes to audience members continuing to be highly engaged and vocal about what they like. Thus, it is unsurprising that we saw a trend for a correlation between the audience scores and the intensity of their cheering. This emphasizes the social nature of hip hop dance and highlights the robust relationship between audience members and performers that exists in hip hop culture.

Hip Hop Training Makes Audience Members More Similar to the Judges

As hypothesized, scores from the hip hop trained audience members were significantly more correlated with the judges' scores compared to the non-dancers. Additionally, the overall first place winner provided by each audience member, which was not required to align with their total scores, revealed that audience members with hip hop training were twice as likely to correctly guess the first place winner (compared to the non-hip hop dancers and non-dancers, both of whom performed below chance). This aligns with previous research showing trained dancers to be more similar to choreographers in their continuous ratings [4], as well as research showing increased efficiency in perceiving dance in dancers compared to novice observers [4,21,22,27]. The fact that the non-hip hop dance trained participants performed below chance level for predicting the winner suggests that general training in dance does not transfer to a nuanced understanding of street dance, highlighting the need for judges trained specifically in hip hop for hip hop competitions.

Limitations and Future Directions

Our study's strengths include its high ecological validity, live data collection, comparison of judges and audience ratings, and objective measurement of synchrony. However, the trade-off with ecological validity was a relatively low number of competing groups, leading to low powered statistical analyses.

This study required a large amount of preparation from the experimenters as well as the dancers, as they needed to choreograph and rehearse their dance routines. We required competing groups to have exactly five dancers to control this factor and to simplify the data analysis. However, it is common in hip hop dance competitions to have much larger competing groups. Future research allowing larger groups to compete would help generalize these findings on the importance of synchrony in group dance.

As this study was the first of its kind, many of the analyses were exploratory and correlational. Additionally, our method of calculating synchrony only included the sections of the dances where dancers were performing identical movement, and only used the dimension of velocity. Future work examining the role that synchrony in space (i.e. position across all three axes), the synchrony of movement to music, and an objective measure of synchrony during non-identical movement would contribute to our understanding of the role synchrony plays in the perception of dance.

CONCLUSION

In a hip hop dance competition, the synchrony of the dancers plays a significant role in the perception of the performance, but motion capture synchrony alone is not able to predict the winner of the competition. Motion capture synchrony does, however, appear to align more strongly with the audience than judges' ratings, and synchrony alone was enough to predict the audience members' mean top score. When developing objective judging criteria, synchrony should be considered important, but not the determining factor of a winning routine, as we found other factors influence judges' scores. These findings contribute to standardization of hip hop judging criteria and inform dancers to focus beyond synchrony when preparing for competitions. Audience members with hip hop training were significantly more similar to the judges in their scoring, emphasizing the role of expertise and familiarity with a style of dance, and highlighting the need for specifically hip hop and street dance trained judges in competition settings. Judges were found to be highly consistent in their scoring, providing evidence that experienced and trained judges are capable of providing reliable scoring in hip hop dance competitions. Overall, this novel and highly ecologically valid study investigating the role of synchrony in hip hop dance competitions showed that there are multiple factors in addition to synchrony that influence the scoring of the highly complex art of hip hop.

Declarations

Competing Interests:

The authors declare no conflicts of interest.

Ethics Approval Statement:

This research was reviewed and approved by the McMaster Research Ethics Board (MREB #1975).

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Author Contributions

C.C. led the design of the study, data collection, analysis of the data, and writing of the manuscript. S.M.R. contributed to the design of the study, data collection, and editing of the manuscript. L.J.T. oversaw the design of the study, data collection, analysis and interpretation, and writing of the manuscript.

Author Contribution

C.C. led the design of the study, data collection, analysis of the data, and writing of the manuscript. S.M.R. contributed to the design of the study, data collection, and editing of the manuscript. L.J.T. oversaw the design of the study, data collection, analysis and interpretation, and writing of the manuscript.

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Data Availability

The data that support the findings of this study are available upon request from the corresponding author.

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Figures

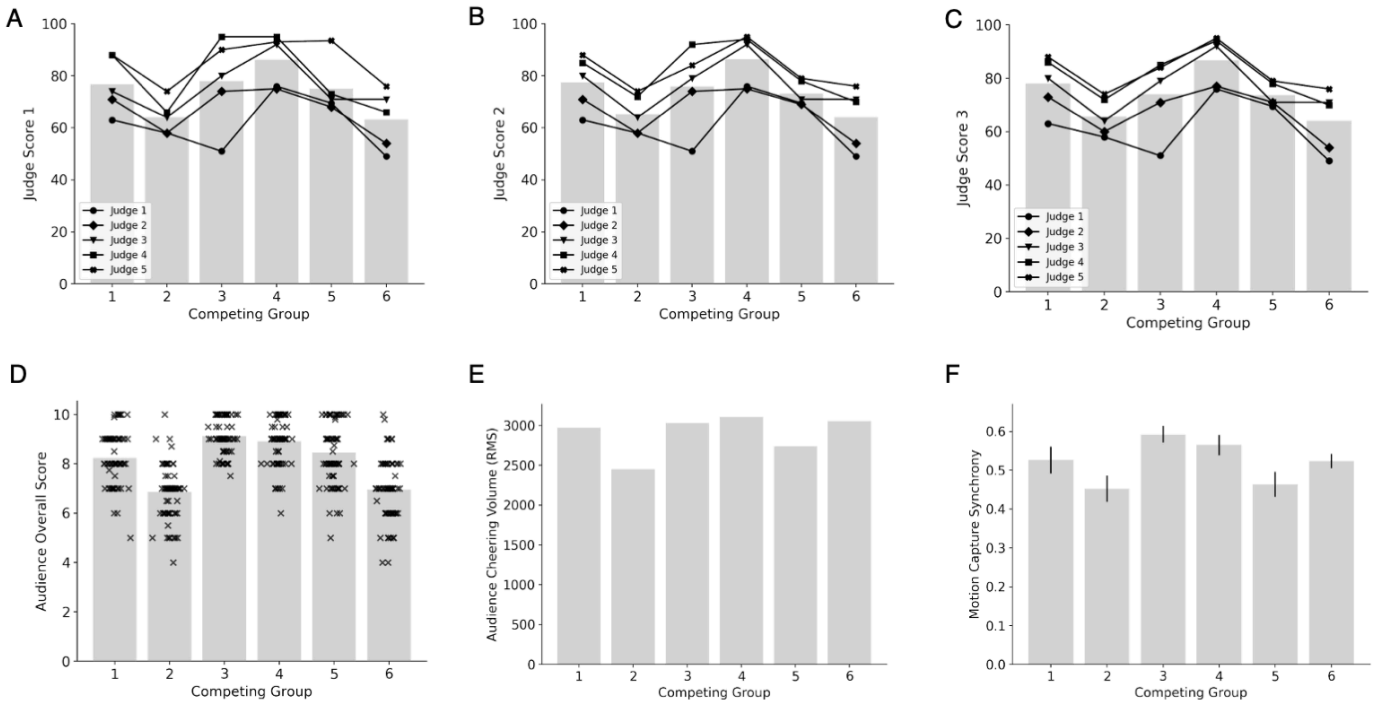


Figure 1

Scores, volume of cheering, and motion capture synchrony across all competing groups. (A-D) Scores for each competing group, scored by (A) Judges immediately after watching the performance, (B) Judges after seeing all competing pieces, (C) Judges after discussing with one another, and (D) Audience members immediately after watching the performance, such that each X represents one audience member participant. (E) Amplitude of audience cheering for each competing group. (F) Motion capture synchrony of each competing group's movement velocity. Error bars represent standard error of the mean across markers.

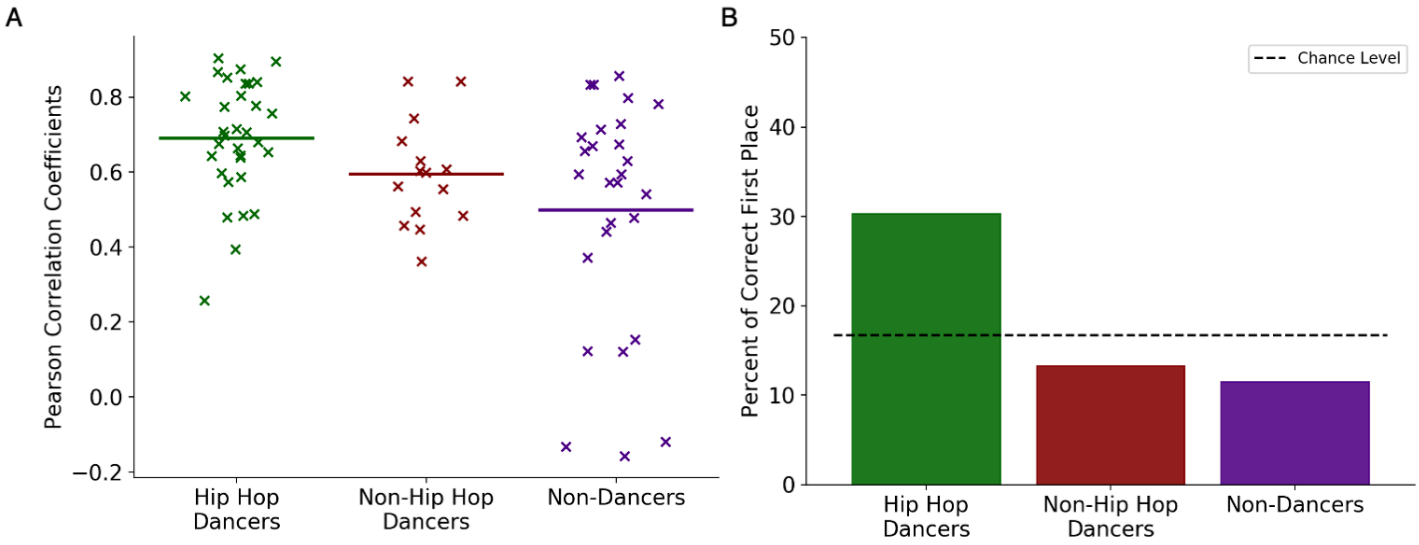


Figure 2

Audience Similarity to the Judges Separated by Dance Training. (A) Audience similarity to judges scores, such that each X represents the Pearson's correlation coefficient for one audience member compared to the judges scores. (B) Percentage of audience members who correctly predicted the winner for each group of training.

Supplementary Files

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- supplementaryhiphopscirep.pdf