A Study to Discover Metrics to Measure Kinesthetic Empathy in Interactive Music Performance

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Figure 1: Body Sample Player performers. A and B on the left, and C and D on the right

Abstract

Kinesthetic empathy is a term used in performance and kinesthetic interaction, defined as the ability of participants to "read, decode and react to each other's input". In prior studies, performers of interactive music self-reported sensing the presence of other musicians. The purpose of this exploratory study was to identify kinesthetic empathy between two individuals in a live electronic performance reported as perceived interactivity. Participants viewed eight videos, both real duets, and spliced solos appearing as real duets, rating each video. The questions guiding this study were: (a) is there a difference in perceived interactivity between the live and spliced duets, (b) is there a relationship between performance rating and perceived interactivity. Results showed a significant difference in the perceived interactivity of the video conditions. Further, the results showed a significant relationship between performance rating and perceived interactivity of the performers. The results suggest that perceived interactivity between performers could be a metric to measure kinesthetic empathy between performers facilitated by an interactive performance system that could be used to objectively measure the effectiveness of design and pedagogical interventions for new interfaces for musical expression.

Keywords

kinesthetic interaction, kinesthetic empathy, interactive electronic music performance, kinesthetic interaction design

1 Introduction

Kinesthetic empathy is a term used in many contexts in the fields of live performance and kinesthetic interaction design. The term kinesthesia is defined as awareness of the position and movement of the parts of the body and is a combination of proprioception (stimuli from inside the organism) and exteroception (stimulation from outside the organism)[31]. Empathy is generally defined as a sympathetic response held in the muscles or body [30]. In live performance, kinesthetic empathy describes the empathetic response an audience feels while experiencing live performance, often referred to as "vicarious performance" [2, 14], "muscular sympathy", "metakinesis", "contagion", and "inner mimicry" [31]. In kinesthetic interaction design, Fogtmann et al define kinesthetic empathy as a situation where multiple users can encode and decode or sense one another's input [23]. In interactive performance, Fogtman's definition has been used to describe a situation where multiple performers sense one another's movement via technologically mediated sonic feedback [26].

Despite several ethnographic studies, where musicians self-reported a sense of connection to one another during technologically mediated performances [2, 25, 26, 28], only a few studies have utilized a quantitative approach to measure this sense of presence [20, 21]. Further, there is no commonly accepted metric to measure this perception. Studies on entrainment in live musical performance suggest that two performers playing the same piece together will have a correlation in their postural sway that is beyond chance [20]. They also suggest that people listening to the musical performance will have an above chance correlation of postural sway with the performer, even when listening to a recording, and that this correlation increases with a higher overall performance rating. These studies have focused on notated pieces of music where both players are performing the same part [20]. As most interactive music systems are improvised, these methods would not be adequate to measure performance correlation. Though much research has been done in the DMI (Digital Musical Instrument) community, it focuses mainly on the effectiveness of design interventions that increase the sense of connection to the instrument know commonly as "familiarity". These interventions often focus on visual cues such as size of

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gesture or added visual feedback rather than the auditory sense. Less research has been done on the kinesthetic connection between performers, or audience perception of this connection. Further, it seems there is no established metric with which to measure this connection.

In the current study, we investigate whether a metric to measure perceived kinesthetic empathy between performers exists in interactive performance. To do this, we asked whether or not observers would notice a difference between real and manufactured duet performances reported by overall performance rating, perceived expressivity of the performance, or perceived interactivity of performers. By finding a difference in response to "real" and "fake" duets for any of these parameters, we can establish that this would be a reliable metric for future studies. To determine this, we created eight videos of a short electronic performance using an interactive performance system known as the Body Sample Player that can track eight discrete joint positions of up to four bodies to control the volume of eight looping samples for each body. In this experiment, two performers were separated by a thick black curtain in order to inhibit any visual or haptic feedback. They then performed a series of duet and solo performances resulting in eight videos that were shown to participants. Two of the videos were real duets, while the rest were manufactured by splicing solo performances together so they appeared to be live duets. Participants then rated the performance by answering five survey questions about each of the eight videos. The data led us to focus on two primary research questions with two additional question to help rule out possible confounding factors: (a) is there a difference in perceived interactivity between the live and spliced duets, (b) is there a relationship between performance rating and perceived interactivity of performers, (c) is there a relationship between preexisting knowledge of electronic music and perceived interactivity of performers, and (d) do observers perceive one or the other performer as a "leader" while viewing the real and spliced performances. In addition to these questions, we also tracked the motion of each performer to see if there were any beyond chance correlations between the performers postural sway that related to higher performance rating. Our results showed no significant correlations running a Pierson correlation. The results did show a significant difference between real and fake videos in perceived interactivity and further, showed a relationship between perceived interactivity and overall performance rating.

2 Background

2.1 Theoretical Background

Traditional musical performance relies on sound cues as well as haptic vibrations and room location to engender a sense of connection between performers [11, 13]. In addition, the tactile nature of traditional instruments helps facilitate a connection between the auditory and sensorimotor system, here referred to as "auditory Kinesthesia" [25, 28]. Research suggests that there is a correlation in movement between musicians during live performance and that this extends to audience members, even when they are listening to a recording of a performance [20]. Further, this correlation is higher when an audience member rates the performance as more expressive [20]. This suggests a kind of kinesthetic empathy between performers as well as performers and observers as defined in the literature on kinesthetic empathy in performance and kinesthetic interaction design as facilitated by the auditory system [2, 14, 23, 31]. Ethnographic studies have shown that musicians self-report feeling the presence and input of other musicians when performing with interactive music systems, even when those systems are networked so that the performers are physically separated [28]. Though this suggests that these systems facilitate kinesthetic empathy between performers, no quantitative study has been done to find a metric for measuring such connections.

2.2 Musical Background: The Body Sample Player

The Body Sample Player is an interactive music system that uses motion tracking to capture eight discrete joint positions to control the volume of eight looping samples that can be changed over the course of a piece of music or dance. The system was first developed in 2012 for an interactive movement and dance opera entitled *3 Singers*[1] [40] and went through several iterations resulting in three different "generations" of technical and artistic design used in a number of different works including *And She Will Sound the Alarm*[2] (2015) featuring the first generation system as well as *Mycelial: Street Parliament*[3] [26] (2016-18) for which both the second and third generation systems were developed. The development and use of these three generations are detailed in other papers cited here [26, 28].

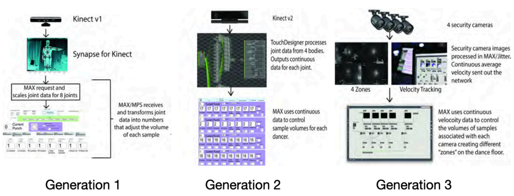

Figure 2: Body Sample Player generation 1, 2 and 3

The second generation design was more recently revisited with a series of usability and structural revisions [25, 28]. This generation originally used touchdesigner to interpret joint data from a Kinect 2 camera, sending that data to MAX/MSP to control the volume of the eight looping samples. This design was later revised for usability and used in case studies to investigate electronic music performance pedagogy [25] and most recently uses a combination of Touchdesigner and Ableton Live with the TD Ableton environment for ease of sample management.

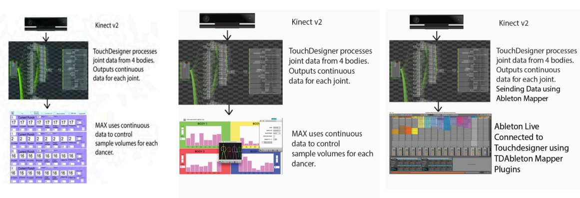

Figure 3: Revised second generation systems

This refinement of the system has resulted in a new work entitled *Rag: A Panhandle Sampler*[4] as well as several works by student composers and performers.[5] [6]

[1]https://youtu.be/HSy8gOgtVXQ
[2]https://youtu.be/2866WrhIWGY
[3]https://youtu.be/2866WrhIWGY
[4]https://youtu.be/iFykJ0DN-vg
[5]https://youtu.be/TtFsTSKk_wQ
[6]https://youtu.be/TtFsTSKk_wQ?si=lnTy1uLTU31PL_mU&t=1885

2.3 Existing Literature on Audience Perception of Interactive Music Performance

There is a significant amount of literature investigating audience perception of interactive music performance and understanding of kinesthetic empathy in the performance of Digital Musical Instruments (DMI's). This research is heavily concentrated in the NIME (New Interfaces for Musical Expression) community [1, 5, 7, 32, 39], but can also be found in other CHI (Computer Human Interaction) communities such as TEI (Tangible, Embedded, and Embodied Interaction) [17, 26, 28], MOCO (Movement Computing) [16], MA (Mostly Audio) [15] and SEAMUS (Society for Electro-actoustic Music in the US) [27]. This literature falls into three broad categories. First, the development of strategies to enhance the audiences "familiarity" with the connection between gesture and sonic result [5, 6, 9, 10, 15, 16, 35, 39]. Second, the development and implementation of systems to track audience perception of laptop or digital performance [1, 4–7, 35, 36, 39]; and third, methods of gauging performer experience using a mix of real/time motion tracking and interview methods in order to give a clearer picture of moment to moment performer experience and correlations in body movement [25, 27, 32].

The first category focuses on ways that the design of interfaces can be used to accentuate the audience's sense of connection or increase their sense of familiarity with the mode of interaction. These designs include factors like size of gesture [5] and multi-modal feedback [9, 10] to create instruments that instill familiarity by design rather than relying on a pre-concert demonstration [6]. In the second category, there are many promising proposals of systems that track real-time responses by observers in order to gain more detailed information in the moment. This work focuses mostly on technological designs and methodologies [4, 10]. In a similar way, some approaches in the third category involve methods such as micro-phenomenology or post performance interviews to help performers connect with the experience of performing from moment to moment [25, 32]. This and other more ethnographic approaches are often mixed with some method of motion tracking to investigate moments of significance in performer experience and particular gestural benchmarks during the performance. Though all of these methods use some parametric prompt such as overall performance rating or perceived expressivity for participants, they rely on relative comparison between different performance conditions, making the assumption that a better rating in one condition or the other has some intrinsic meaning. Such methods would not be sufficient to answer the question of whether an observer will notice the presence of kinesthetic empathy between two performers, or whether there is some above chance correlation in their movement that would suggest such a connection.

2.4 Prior Research into Kinesthetic Empathy Between Performers of Interactive Music Systems

Prior research on Kinesthetic Empathy between performers has relied largely on ethnographic data obtained through interviews with a limited number of performers communicating their experiences before and after certain interventions. In several studies, musicians have self-reported feeling the presence of other musicians using interactive music systems [25, 28]. This reporting happened even when separated or facing away from each other as well as in telematic performance. This sense of connection was also shown to increase when performers were given specific training exercises that helped develop a connection between their auditory and sensorimotor system that we refer to here as "auditory kinesthesia" [25]. In all of these cases, the experiences the musicians reported could be described in terms of kinesthetic empathy given the aforementioned definitions in music, dance, and kinesthetic interaction design.

2.4.1 Kinesthetic Empathy in Performance Systems for Dance. The development of the Body Sample Player system was instigated by two main artistic desires. The first was to increase an embodied connection between performers, driven purely by sonic cues. The second was to make the connection between the movements and sound more apparent to audience members [26]. These desires were later aligned with an unrealized desire to achieve kinesthetic empathy in the field of kinesthetic interaction design [23]. It was shown that through a series of technical and sound design interventions, performers were better able to sense the presence and movement of their fellow dancers based on the sonic response. It was also shown that by allowing audience members to interact with the performance system as a kind of sound installation before the performance, their appreciation for the dance performance was heightened by their embodied experience with the instrument itself [26].

2.4.2 Kinesthetic Empathy in Remote Performance Systems. During the 2020 pandemic, many modes of human contact were facilitated by online communication. However, standard internet latency inhibited the instantaneous bi-directional communication necessary for traditional forms of music [22, 29]. In the summer of 2020, systems were developed that allowed musicians to have meaningful musical interactions [28]. These systems minimized latency by using small packets of control data rather than audio streaming. Indirect improvisational performance modes also minimized the effects of latency during performance. In three different case studies, musicians performing with these systems reported a sense of musical connection that they had not felt since the start of the pandemic. Using the remote version of the Body Sample Player, two experienced performers reported feeling the same sense of musical connection they felt when engaging with the instrument in the same space [28].

2.4.3 Pedagogical Interventions With the Body Sample Player. A series of exercises or "etudes" were developed for the Body Sample Player system, designed to help performers form a greater sense of embodied connection to the instrument or "auditory kinesthesia" [25]. A training intervention involving these exercises was the basis of a case study in which experienced electronic performers were asked to work with the instrument for a number of weeks, both before and after the exercises. After each session they engaged in short performances with the system followed by a series of interview questions and survey responses to gauge their experience. The performers both self-reported a greater sense of connection after the exercises as well as a perception that there were higher levels of virtuosity that could be achieved with the instruments through continued practice.

3 Experiment

3.1 Method

3.1.1 Musicians. Two pairs of electronic performers (A and B, C and D as pictured in figure one) engaged in a live duet and solo performances using the Body Sample Player. The first pair consisted of an electronic performance duo that included one composer/performer and one classically trained pianist. Both performers had been trained on the performance system and had performed with it in the past. The second pair consisted of a dancer who had worked with the system since its inception in 2016 and the composer and instrument builder who created the system. All performances were video recorded.

3.1.2 Participants. Forty-three participants watched the videos and rated the performances by answering a series of survey questions. The questions were delivered in a Qualtrics survey in which each of the eight videos was shown immediately followed by a series of questions rating various aspects of the performance. The participants were mostly drawn from a pool of students ages eighteen through twenty-five with a small number of older performers or faculty members taking the survey. Participants were asked a single demographic question regarding their familiarity with interactive musical performances. Fifteen of them expressed little to no familiarity, eleven expressed a general familiarity, and sixteen expressed a high level of familiarity. One participant indicated they were an electronic or interactive performer themselves.

3.1.3 Musical Instrument. The experiment was designed around duet and solo performances of the Body Sample Player instrument. This instrument was chosen because of the direct and simple nature of the interaction as well as it's overt visual element. We felt it was important to present video performances rather than just recordings since the connection between movement and sound is essential to the perception of interactivity and expression.

3.1.4 Musical Materials. The performances were each around ninety seconds long. All performances utilized consistent musical material where each joint played a different note sung by a human voice that outlined a particular chord referencing a particular human emotion. For example, joy outlined a C major chord while fear outlined an F minor seventh chord. Each player had a different chord and their movements created various harmonic combinations. The performers were all familiar with these sonic materials from previous performances and studies.

3.1.5 Performance and Documentation Apparatus. The two pairs of performers were situated on either side of a thick black curtain to inhibit visual and haptic cues, then surrounded by four speakers in a standard quadrophonic (Left/Right Front and Left/Right Rear) configuration. They then delivered both duet and solo performances that were audio and video recorded. Motion capture data for each performer was also recorded in real-time.

The videos were shot with a built-in camera on a Motorola MOTO g-powered 2022 phone (Motorola, Chicago, IL). Audio in all four channels was recorded in Ableton Live and later mixed in a binaural rendering with the original room sound. This was done to emulate the quadraphonic sound the performers would have heard in the room. Finally, the spliced solo videos were edited together using Clipchamp (Clipchamp, Brisbane, Australia) to create videos that gave the illusion that two separate performances, given at different times, were actually performed together at the same time. Joint position data of both bodies from the Kinect camera was captured using MAX/MSP. This data included the cardinal position of all of the join positions controlling audio (left and right hand X and Z coordinates, left and right elbow X coordinates, and left and right knee Y coordinates) as well as X, Y, and Z coordinates for both left and right shoulders, hips, and head. Qualtrics (Silver Lake, Seattle WA) was used to deliver an online survey with eight videos with five survey questions per video.

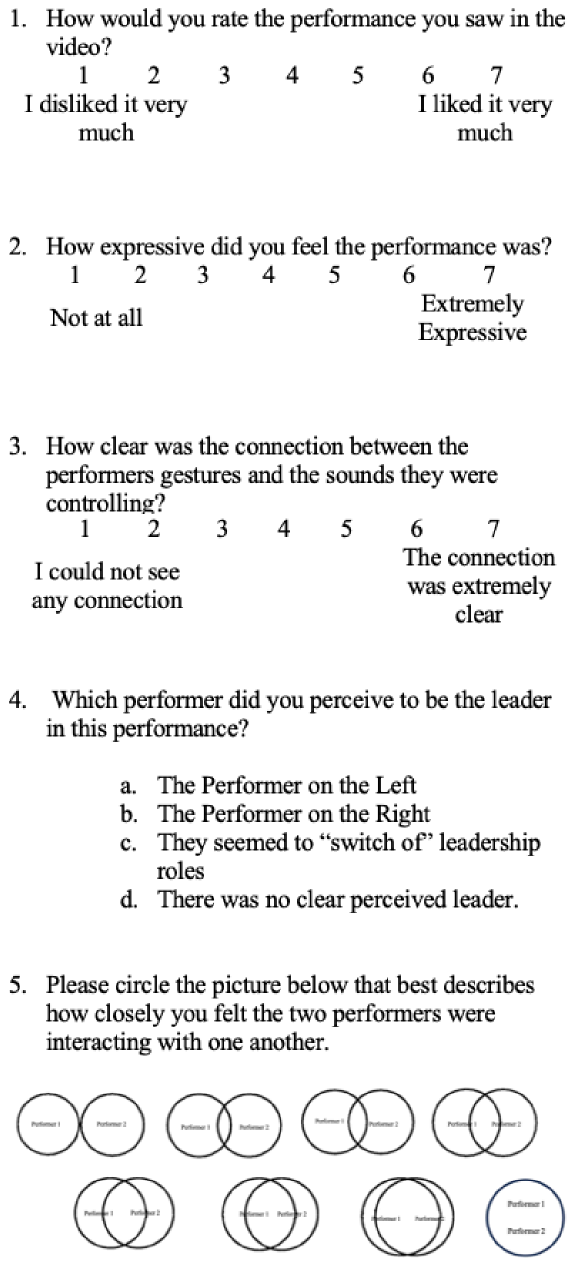
1. How would you rate the performance you saw in the video?
   1 2 3 4 5 6 7
   I disliked it very much — I liked it very much
2. How expressive did you feel the performance was?
   1 2 3 4 5 6 7
   Not at all — Extremely Expressive
3. How clear was the connection between the performers gestures and the sounds they were controlling?
   1 2 3 4 5 6 7
   I could not see any connection — The connection was extremely clear
4. Which performer did you perceive to be the leader in this performance?
   a. The Performer on the Left
   b. The Performer on the Right
   c. They seemed to "switch of" leadership roles
   d. There was no clear perceived leader.
5. Please circle the picture below that best describes how closely you felt the two performers were interacting with one another.

Figure 4: Survey questions

3.1.6 Procedure. Each pair of performers developed three duet performances using the Body Sample Player instrument. The performers were separated by a black curtain so they could not see one another's movement, however they could hear the results of each other's performance. Each performer then did three solo performances on the same side of the curtain as they were in during the duets. One live duet from each pair was selected to be shown to viewer participants. The solo videos were then spliced together in combinations so that it appeared that each combination had performed two duets (A/B X2, C/D X2, A/D X2, B/C X2). The end result was eight videos, two of which were real (A/B 1 and C/D 1) with the rest being spliced solos.[7] All eight videos were then shown to a group of general participants who answered a series of questions about each video. The survey questions are pictured in figure four.

The first three questions were rated using a Likert scale of one to seven. The circles in question five were derived from previous research studies in cognitive psychology where musicians self reported how "in sync" they felt they were with other musicians [21]. We felt this added visual element would help facilitate a better understanding of the question.

3.1.7 Measure. An initial look at the results demonstrated that there was no significant difference between any of the videos for questions one through four. Statistical tests were run to answer the three primary questions in the study. First, a Friedman one-way repeated measure analysis of variance of ranks (Friedman test) was used to test for the differences in rating of perceived interactivity (question five) between the video duet combinations. An alpha level of .05 was established a priori. To determine the video combinations that had a significant difference, the Wilcoxon signed-ranks test was used for post-hoc analysis. Finally, a Spearman's correlation was run to assess the relationship between overall performance rating and the rating of perceived interactivity as well as a correlation between familiarity with electronic music and perceived interactivity.

3.2 Results

For this study, we focused on three primary research questions.

3.2.1 Research Question One: Is there a difference in perceived interactivity when performers are live and together and when performers are performing solo and then spliced together? A Friedman one-way repeated measure analysis of variance of ranks showed a significant difference between the eight video duet combinations of real and spliced videos, Fr (7, 23) = 38.84, p <.001. Further, post hoc analysis was run using a Wilcoxon signed-ranks test for each video combination.

The post-hoc analysis in Table 2 below shows that the first real duet video (video one, performer A and B) had a significant difference between all spliced video combinations, except for video seven, which was a spliced video of performer C and performer B, as shown in Table 2. There was no significant difference between the real duet videos (video one and video two). Additionally, the second real video (video two, performer C and D) also had a significant difference between all spliced videos, except for video seven. It is also of interest that video seven had a significant difference with all but two of the other spliced videos.

Video key (the letter represents each of the four performers)

Video 1 - A and B Real Duet	Video 5 - A and B Splice
Video 2 - C and D Real Duet	Video 6 - A and D Splice
Video 3 - B and C Splice	Video 7 - B and C Splice
Video 4 - A and D Splice	Video 8 - C and D Splice

Table 1: Key for videos that participants watched showing which combination of performers appear in which video

Variable	*M*	*SD*	1	2	3	4	5	6	7
Video 1	5.12	2.24							
Video 2	5.15	1.91	0.168						
Video 3	3.85	2.36	2.517*	2.223*					
Video 4	3.33	2.16	2.881**	3.237**	1.049				
Video 5	3.06	1.67	4.051**	4.361**	1.439	0.404			
Video 6	3.58	2.58	2.651**	2.979*	0.861	0.531	1.022		
Video 7	4.82	2.36	0.589	1.091	1.752	2.559**	3.322**	2.264*	
Video 8	3.44	2.00	3.086**	3.775**	1.159	0.061	0.407	0.907	3.327**

*Note, bold indicates the two live duets. * indicates p <.05. ** indicates p <.01.*

Table 2: Wilcoxon signed-ranks posthoc analysis of Friedman test

3.2.2 Research Question Two: Is there a relationship between performance rating and perceived interactivity of performers? Aa Spearman's correlation was run to assess the relationship between the overall performance rating and the rating of perceived interactivity between performers. A positive correlation was found between performance rating and perceived interactivity score, r_s = .487, p = <.001.

3.2.3 Research Question Three: is there a relationship between preexisting knowledge of electronic music and the perceived interactivity of performers? A Spearman's correlation using repeated ranks was run to assess the relationship between familiarity with electronic music and perceived interactivity. No significant correlations were found for any video combination R_s = 0.01, p = 0.96

3.2.4 Other Survey Questions. Leader and follower: A comparison was made to determine if there was a perceived leader and follower relationship, or no leader present in each duet video. A Chi-Square test was calculated with a significance level (α) of .05 established a priori. A significant difference was found between the three videos with regard to perceived leader-follower relationships. Video 1, χ^2 (3) = 45.57, p = <0.001, with performer A being listed more often as the leader. Video 4, χ^2 (3) = 27.24, p = <0.001, again with performer A being listed more often as the leader through the performance. The final video that contained significance was video 7, χ^2 (3) = 20.21, p = <0.01, with the most frequent response being the perception of the leader switching throughout the video between performers B and C. No other significance was found for other video conditions.

When asked which performances had a higher expressivity rating (survey question one), the videos expressivity appeared to diverge from the reported interactivity. Video one was reported to be the third least expressive (M = 4.72), video seven was the second most expressive (M = 5.53), and the second live duet was rated as the third most expressive (M = 5.17). The remaining videos were rated as follows: video three (M = 5.56), four (M = 5.00), five (M = 4.38), six (M = 4.71), and eight (M = 5.06).

4 Discussion

4.1 Implications

The results suggest that a general audience can sense a greater level of interactivity when two performers are actually performing together. Given the definitions of kinesthetic empathy used in kinesthetic interaction design, prior ethnographic research has suggested that modern digital musical instruments such as the Body Sample Player help facilitate kinesthetic empathy in a

[7] https://www.youtube.com/playlist?list=PLNbP6Og3P-_CoQUsV8BFQ1wWCFM6H511-

way that was un-realized in the examples used by Fogtman et al. [23, 26, 28]. The results in the current study suggest that in a real performance, where performers self-report the presence of their fellow performers purely through the auditory sense, this sense of connection (or kinesthetic empathy) is observable by a general audience. This is the most important finding in our study as it suggests that perceived interactivity is a reliable metric to measure kinesthetic empathy between two performers.

When analyzing the data, expressivity appeared to have no impact on interactivity, nor did it seem to impact the overall performance rating. The correlation between overall performance rating and interactivity rating implies a relationship between these two metrics that could be further investigated in future studies. The lack of correlation between the familiarity of the participant with the performance of electronic music and the interactivity rating poses an interesting difference from the findings of previous research in which familiarity appears to increase the overall performance rating of interactive musical performance [5, 6, 9, 10, 15, 16, 35, 39]. In this case, we were comparing observer familiarity with the perception of interactivity rather than the overall performance rating or expressivity. The lack of correlation between perceived interactivity and familiarity would seem to strengthen our findings, as observers of all backgrounds might rate the performance at the same level.

Although the two real videos each reported a significant difference with five out of the six spliced videos, the one spliced video that did not report a difference with the two real videos (video seven) only had a significant difference with three of the other spliced videos, suggesting a much weaker difference than the real videos. This helps to reinforce the importance of the significant differences found between the real and spliced performance videos.

The final question that was investigated involved the leader-follower relationship. Previous research on leader-follower relationships in musical performance uses motion or brainwave tracking [12, 18] or audience observation of orchestras with and without conductors [3, 37]. Of these, only one uses observer-interview to determine their enjoyment of the music based on the perception of this leader-follower relationship [3]. No study in the literature attempts to correlate the perceived leader/follower relationship with interactivity using a qualitative approach. To account for possible confounding variables in the current study, it was important to determine if the participants perceived the presence of a leader-follower relationship, which might correlate to higher performance or interactivity ratings [3]. As videos one and four were the only ones found to have a significant leader-follower relationship, while having only the second and second to last highest interactivity scores respectively, there does not appear to be a clear link between interactivity rating and the presence of a leader-follower relationship.

4.2 Limitations

It is of interest that in video seven, being the only fake video that showed no significant difference with the two real videos, both performers were wearing red shirts whereas in all but one of the other spliced videos, either one or both performers were wearing dark clothing. In the real videos, performers were each wearing a distinctly different color to avoid any bias based on color. Several studies have suggested that there is a bias toward the color red in ratings and other judgment calls in social interactions and sporting events [24, 33]. In contrast, the other fake video that featured the same two performers both wearing red shirts (video three) did show a significant difference with videos one and two.

Another aspect that may have led to a higher performance rating of video seven could be the amount of overall movement present in this video. It has been noted in prior studies of music performance that higher levels of movement correlate to higher performance ratings [8, 19, 34]. In either case, we feel these possible confounding factors on perceived expressivity do not diminish the significant differences found in the interactivity score.

Finally, as addressed in a previous section, the performers were motion tracked in eight individual joint positions as well as five additional body parts across all relevant dimensions including the head, left and right hips, and left and right shoulders for a total of twenty four data points. In a preliminary version of the study, a Pierson correlation gave no clear findings that could correspond to the responses of the study participants or beyond chance correlations between data points for each performer.

4.3 Future Research

The findings in this study set a groundwork by demonstrating a consistent metric to measure the presence of kinesthetic empathy in musical performance. More studies should be conducted to replicate and strengthen these findings. For future studies, we propose using real-time response systems to track observer response to each question throughout the performance. We also hope to investigate other methods to successfully measure any significant correlation of body movement or postural sway such as “cross wavelet analysis” in which multiple correlations are run using various windows of time throughout the performance [18, 38].

We also hope to use this metric in future to reinforce the findings in ethnographic studies that attempt to gauge the effectiveness of pedagogical and design interventions for interactive musical instruments. By comparing performers’ rating of the feeling of kinesthetic empathy with their fellow performers to observers’ ratings of perceived interactivity, we can reinforce the connection between the two metrics. As the ultimate goal of our research is to broadly improve the design of new interfaces for musical expression as well as developing pedagogical methods for the performance of these instruments, we feel that this line of inquiry represents a significant contribution to the discussion in the the field of interactive and digital musical instrument performance.

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6 Ethics Statement

This study has acquired ethical approval from the author’s institution. All participants provided informed consent before participating in the study. The anonymity and confidentiality of the participants were guaranteed, and participation was completely voluntary.

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