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Embodied Harmony: The Role of Singer Body Movement in Enhancing Choral Expressivity and Ensemble Coordination

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ABSTRACT: This study investigates the impact of singer body movement on ensemble coordination and perceived expressivity in choral performance. Grounded in theories of embodied music cognition and entrainment, the research explores how varying degrees of movement no movement, slight sway, and full body sway affect acoustic precision, synchrony, and audience evaluation. Using a within subject factorial design, 24 university level choir members performed under each movement condition. Data were collected through multi microphone recordings, OpenPose based motion tracking, and blind evaluations by expert and non expert listeners. Acoustic measures included pitch deviation, LTAS, and SPL; movement metrics captured sway amplitude and synchrony; perceptual ratings addressed expressiveness, articulation, and timing. Results showed that slight sway consistently produced better outcomes across all measures. It yielded the lowest pitch deviation and the highest movement synchrony. Perceptual ratings were also significantly higher compared to no movement or full body sway. In contrast, excessive movement increased pitch instability, disrupted blend, and reduced synchronization. These findings highlight the functional role of calibrated movement in choral performance. Incorporating slight, synchronized motion can enhance ensemble cohesion and elevate audience experience without compromising acoustic integrity. The study offers empirical support for movement integrated pedagogies and suggests broader applications across ensemble types and performance genres.

Keywords: Choral Performance, Singer Movement, Visual Expressivity, Ensemble Coordination, Embodied Music Cognition, Entrainment.

INTRODUCTION

In ensemble music performance, visual and kinesthetic elements play important roles that extend beyond auditory considerations. While sound has traditionally been the main focus of choral scholarship, recent studies show that visual and physical cues influence both performer coordination and audience responses. These cues manifested through gestures, postures, and

expressive movements form a visual language that conveys interpretive intentions, augments timing synchronization, and enhances musical expressivity.

The significance of visual communication in ensemble settings is supported by a growing body of empirical research. Conductors, for instance, operate as visual anchors whose gestures shape ensemble cohesion and interpretation. Kumar & Morrison (2016) demonstrate that conductor gestures have a marked effect on the perception of ensemble performance, suggesting a direct link between visual input and auditory evaluation. Furthermore, audience perception is also intimately tied to the visual dimension of performance. Zhang et al. (2024) report that audiences derive greater enjoyment and emotional engagement when observing performers' body movements, underlining the integrative nature of sensory processing in musical appreciation.

This integrative engagement between auditory and visual stimuli finds further support in the domain of choral pedagogy. Historically, instructional models in choral settings emphasized vocal technique and textual interpretation, often neglecting kinesthetic training. However, a pedagogical shift is evident in recent years, reflecting an understanding of the value of bodily awareness in vocal performance. Bishop et al. (2023) discuss the evolving emphasis on integrating movement into choral instruction, showing how kinesthetic strategies can improve tone quality, phrasing, and ensemble cohesion. The development of body based techniques is now seen as essential not only for enhancing the physical health of singers but also for deepening their interpretive capabilities and sense of ensemble.

These pedagogical innovations resonate with theoretical frameworks that emphasize the embodied nature of musical cognition. One such framework is the theory of entrainment, which posits that individuals synchronize their biological rhythms such as heartbeat or breathing with external rhythmic stimuli. In ensemble music, this synchronization process is not merely internal but facilitated through observable cues. D'Amario et al. (2018) identify visual signals as instrumental in achieving entrainment, demonstrating that such cues help performers align their timing and coordinate their gestures. Le (2022) extends this argument, suggesting that movement establishes shared temporal frameworks that underlie successful musical collaboration. These frameworks serve as non verbal channels of communication, guiding performers as they adjust their actions in real time in response to the musical behavior of their peers.

Audience perception also plays a pivotal role in shaping the perceived quality and effectiveness of ensemble performances. Studies on multimodal perception have shown that visual congruence when gestures align with auditory output enhances the audience's evaluative and emotional experience. Meals et al. (2019) found that when visual and auditory elements are congruent, audiences report higher levels of satisfaction and are more likely to perceive the performance as expressive and cohesive. These findings suggest that visual expressivity, ranging from facial expressions to full body movement, is not merely decorative but deeply functional in shaping musical meaning for both performers and observers.

The expressivity of movement in performance has been further validated through empirical research. Chang et al. (2019) show that performers who exhibit visible emotional engagement

through body movement are perceived as more connected to the music. Similarly, Bishop et al. (2023) and D'Amario et al. (2022) document the correlation between expressive movement such as body sway and the communication of emotion in ensemble contexts. These movements act as vectors for emotional transmission, fostering a shared affective atmosphere between performers and audiences. Such findings align with the notion that musical performance is inherently a multimodal experience that involves more than sound alone.

The cognitive mechanisms underpinning these interactions have also been the focus of scholarly inquiry. Movement, ranging from subtle gestures like head nods to more pronounced body sways, serves as a tool for synchronization and mutual responsiveness within an ensemble. Chang et al. (2017) describe how these movements function as anticipatory cues, allowing ensemble members to predict and align with each other's musical actions. Laroche et al. (2022) reinforce this perspective by illustrating how musicians adjust their bodily behaviors in response to auditory input, creating a dynamic feedback loop that enhances both timing precision and expressive delivery.

Collectively, these studies underscore the importance of bodily engagement in ensemble music making. Visual and kinesthetic dimensions are not ancillary but integral to the coordination, communication, and expressivity that define successful ensemble performance. The evolution of choral pedagogy, the application of entrainment theory, and the cognitive science of synchronization converge to suggest a new paradigm in ensemble music studies one in which the body is central to both the execution and perception of music.

Within this context, the current study investigates how varying degrees of singer movement specifically no movement, slight sway, and full body sway affect ensemble coordination and audience perception of expressivity. The central hypothesis posits that slight, synchronized sway enhances ensemble cohesion and perceptual expressiveness, whereas excessive movement may compromise vocal accuracy and blend. By integrating motion tracking, acoustic analysis, and perceptual evaluation, this research aims to clarify the functional role of movement in choral performance and contribute empirical evidence to support the integration of embodied strategies in choral pedagogy.

Through this inquiry, the study seeks to bridge theoretical insights with practical application, offering a comprehensive understanding of how the body participates in the collaborative act of music making. The findings promise to inform rehearsal practices, conductor training, and performance design, ultimately enriching the pedagogical and aesthetic dimensions of choral artistry.

METHOD

This study employed a within subject factorial design to investigate how varying levels of singer body movement affect ensemble coordination, acoustic outcomes, and perceptual expressivity in

choral performance. The methodological framework integrated motion tracking, acoustic analysis, and perceptual evaluation to provide a comprehensive examination of the research questions.

The participants consisted of 24 university level singers enrolled in a mixed SATB choir. All participants had moderate ensemble singing experience (ranging from 2–6 years) and received the same preparatory rehearsal regimen. The selection criteria ensured vocal balance across sections and consistency in musical familiarity.

The performance protocol was structured around three body movement conditions: (a) no movement, (b) slight sway (natural torso and shoulder motion), and (c) full body sway (pronounced motion from hips and shoulders). Each singer performed the same piece under all three conditions, allowing intra subject comparison. The repertoire chosen was a contemporary SATB composition with moderate rhythmic and dynamic demands, ensuring that expressivity and coordination could be adequately measured across all conditions.

To measure body movement, OpenPose was employed as the primary motion tracking system. OpenPose is a robust 2D keypoint detection framework capable of capturing real time human poses through video input (Gaggioli et al., 2016). It enabled the researchers to extract sway amplitude, periodicity, and synchrony metrics from multi angle video recordings. OpenPose's validated architecture, which employs a multi stage convolutional neural network, has been effectively used in performance studies to quantify posture and motion patterns in ensemble contexts(Sabharwal et al., 2022).

Additionally, video footage was cross validated using frame by frame analysis and, where feasible, compared against motion data obtained from alternative depth camera systems, affirming data consistency. As Chang et al. (2017) indicate, real time body sway data can reflect leadership and communication roles within ensembles, making these motion metrics essential for understanding interpersonal musical dynamics.

Audio was captured using a stereo main pair in ORTF configuration supplemented by close microphones positioned near each section (SATB). Acoustic parameters were extracted using software capable of real time pitch tracking and spectral analysis. Pitch deviation was measured in cents against a MIDI based reference, while LTAS provided insight into the dynamic balance and spectral distribution across the vocal range. These metrics allowed for precise measurement of vocal blend and intonation accuracy (Bishop et al., 2023; Jakubowski et al., 2017).

The SPL (Sound Pressure Level) values were also recorded using calibrated meters to assess vocal dynamics across movement conditions. LTAS and pitch deviation, in particular, are reliable indicators of ensemble vocal health and cohesion, allowing instructors to identify potential imbalances (Sabharwal et al., 2022; Tagiltseva et al., 2020).

Perceptual data were gathered through blind evaluations conducted by a 10 member panel composed of five expert musicians and five non musicians. Each panelist evaluated video only, audio only, and audio video recordings. Ratings were collected using a structured rubric modeled

after the Choral Performance Assessment Tool, which quantifies expressiveness, articulation, timing, intonation, and dynamic control (Demorest et al., 2016; Nugrahhu et al., 2023).

Panelists used a 7 point Likert scale to rate each condition across these dimensions. The use of both expert and non expert listeners allowed for the examination of potential perceptual disparities influenced by musical training, as observed in prior literature (D'Amario et al., 2019). To ensure inter rater reliability, intraclass correlation coefficients (ICCs) were calculated for each perceptual dimension.

Data analysis followed a mixed quantitative approach. Repeated Measures Analysis of Variance (RM ANOVA) was used to assess differences between movement conditions across acoustic and perceptual metrics. Post hoc comparisons were adjusted using Bonferroni corrections. Correlational analyses were conducted to evaluate the relationship between sway synchrony and perceptual ratings, with Pearson's r used as the primary coefficient.

Movement synchrony was operationalized through lag 0 cross correlation values between individual motion time series. This allowed for the detection of real time alignment among singers, supporting the premise that greater synchrony reflects stronger group cohesion. Motion periodicity was calculated in Hz, indicating the rhythmic stability of bodily movement under different task demands.

To triangulate findings, the study synthesized results across technological, perceptual, and acoustic domains. By combining OpenPose data with audio analysis and subjective ratings, the methodology enabled a holistic examination of how movement influences ensemble dynamics. Bishop et al. (2019) emphasize the value of integrating visual and auditory assessments to capture the full complexity of ensemble performance.

This multimodal methodology aligns with emerging trends in ensemble music research that advocate for blended measurement approaches (Clayton et al., 2020). Such integration is essential for capturing the nuanced interplay between physical movement, acoustic precision, and perceived musical expressivity.

The study received approval from the institutional research ethics board. Participants provided informed consent, and their identities were anonymized in all data reporting and analysis. Video data were stored securely and used solely for research purposes.

The methodological design of this study reflects a comprehensive approach to exploring the influence of singer movement on choral performance. By integrating motion capture, acoustic measurement, and perceptual evaluation, the study offers a multifaceted view of ensemble dynamics. These methods not only reflect the current state of technological advancement in music research but also promote evidence based practices for enhancing choral pedagogy and performance quality.

RESULT AND DISCUSSION

This chapter presents the findings of the study across three key dimensions: acoustic outcomes, perceptual ratings, and movement synchrony. The results are framed within the context of previously validated performance thresholds and current literature on ensemble movement, acoustic precision, and expressive evaluation.

Acoustic Outcomes

Pitch deviation, spectral features, and sound pressure levels (SPL) were measured across the three movement conditions. As shown in Table 1, the lowest pitch deviation occurred in the slight sway condition (−27.67 cents), while the highest was found in the no movement condition (−58.31 cents). The full body sway condition also exhibited increased pitch variability (−43.55 cents), suggesting a potential trade off between movement and pitch precision.

These findings align with established thresholds of perceptible pitch deviation, typically noted as ±20–30 cents (Sundberg, 2016). Deviations exceeding this range, as seen in the no movement and full body sway conditions, likely contributed to decreased perceived intonation accuracy. Lee et al. (2020) reinforce this, noting that even small, consistent deviations within a phrase can influence listener perception.

Table 1: Acoustic Metrics by Movement Condition

Condition	Pitch Deviation (cents)	LTAS Shift (dB)	SPL (dB)
No Movement	58.31	+0.80	74.2
Slight Sway	27.67	+1.20	74.5
Full Body Sway	43.55	+2.50	76.3

LTAS values, which reflect overall timbral and harmonic richness, increased across all conditions but peaked in the full body sway condition. This may indicate enhanced resonance or harmonic presence due to physical openness in posture (Langley, 2022; Nápoles et al., 2021). However, increased LTAS did not correlate with improved pitch accuracy, implying that vocal blend may suffer if movement is not precisely controlled.

SPL readings demonstrated higher dynamic projection during full body movement, confirming Frühholz & Ceravolo (2018) assertion that physical alignment with breath and vocal output can enhance projection. Frizzell & Windsor (2021) also noted that active movement tends to increase SPL, which may contribute to greater audience engagement.

Perceptual Ratings

Ratings of expressiveness, articulation, and timing accuracy were highest in the slight sway condition across expert and non expert panelists. Slight sway achieved mean expressiveness scores of 6.2 out of 7, compared to 5.2 in full body sway and 4.5 in no movement.

Table 2: Perceptual Ratings (Mean ± SD)

Condition	Expressiveness	Articulation	Timing Accuracy
No Movement	4.5 ± 0.8	4.3 ± 0.6	4.7 ± 0.5
Slight Sway	6.2 ± 0.7	5.9 ± 0.9	6.0 ± 0.8
Full Body Sway	5.2 ± 1.0	5.0 ± 0.7	5.3 ± 0.6

Listeners appeared to prioritize tonal quality, expressive clarity, and ensemble blend dimensions emphasized in prior studies (Demorest et al., 2016; Xiwen et al., 2024). Visual cues also significantly enhanced perceptual ratings, particularly in conditions where movement was synchronized and expressive (Langley, 2022). Notably, expert listeners focused more on technical aspects like pitch accuracy and blend, while non experts placed greater emphasis on emotional impact and engagement (Chandna et al., 2022).

Judgment consistency increased in the audio video and video only conditions compared to audio only, aligning with D'Amario et al.'s (2019) findings that visual information improves consensus and perceived cohesion in ensemble settings.

Motion Synchrony and Amplitude

Sway amplitude and motion synchrony were extracted using OpenPose tracking. The ideal sway amplitude for maximizing synchrony was between 2–3 cm. Synchrony was highest under the slight sway condition, with cross correlation values exceeding $r = 0.80$. In contrast, the no movement condition yielded low synchrony ($r \approx 0.40$), and full body sway demonstrated inconsistent movement trajectories, reducing coordination ($r \approx 0.55$).

Task complexity was a strong determinant of coordination. Performing in unison supported greater bodily alignment, while the canon condition, which required staggered entries, produced lower synchrony scores. This finding supports Redford et al. (2017) and Chan et al., who note that complex textures demand more advanced coordination strategies, including heightened visual cue reliance.

Correlational Analysis

Significant positive correlations were observed between sway synchrony and expressiveness ratings ($r = 0.52$, $p < .05$). A moderate negative correlation was found between full body movement and pitch accuracy ($r = 0.39$), suggesting that excessive movement may impair vocal precision. These

results support Langley's (2022) and Chang et al.'s (2017) claims that expressive movement must be deliberate and regulated to avoid undermining acoustic outcomes.

Overall, the results demonstrate a non linear relationship between movement and ensemble effectiveness. Slight movement enhances synchrony and perception without sacrificing acoustic precision, whereas full body movement, while visually engaging, introduces performance variability.

Overview of Findings

This study confirms the importance of body movement in effective choral performance. By comparing three conditions no movement, slight sway, and full body sway the results show that moderate, synchronized movement enhances coordination and expressivity. In contrast, excessive movement may reduce vocal accuracy and blend, highlighting the need for balance between visual expressivity and acoustic precision. These outcomes highlight the need for an evidence based understanding of the impact of body movement on various dimensions of ensemble performance and call for a nuanced integration of movement into both rehearsal and pedagogical contexts.

Theoretical Interpretation

The optimal performance outcomes observed under the slight sway condition are consistent with principles from embodied music cognition and entrainment theory. These frameworks emphasize that bodily movement is not merely decorative but deeply functional in shaping temporal alignment and musical coherence. The embodied nature of musical understanding implies that physicality plays a central role in the ways performers conceptualize and execute musical intentions. The results suggest that even subtle movement on the order of 2–3 cm sway amplitude can produce meaningful improvements in ensemble synchrony and listener evaluations. This echoes Chang et al.'s (2017) observation that synchronized body movement operates as a non verbal communication channel among ensemble members, enhancing internal timing and cohesion. The positive correlation between movement synchrony and perceived musicality underlines the importance of bodily awareness in shaping both technical execution and artistic output.

Audience Perception and Visual Influence

The perceptual ratings confirm that movement enhances musical expressivity when executed in a controlled and context sensitive manner. Listeners both experts and non experts consistently rated slight sway as the most expressive condition. This supports Langley's (2022) findings that visually engaging performances are often perceived as more emotionally compelling, even when auditory output remains constant. Importantly, these findings also underscore the multidimensional nature of ensemble performance assessment, where visual and auditory cues intersect to shape audience judgments. As D'Amario et al. (2019) argue, the addition of visual information enhances perceptions of ensemble unity and "togetherness," providing a more complete sensory experience for the listener. The interplay between auditory and visual information has implications for how performances are staged and how movement is incorporated to reinforce or clarify musical structures and expressive intent.

Pedagogical Implications

From a pedagogical perspective, the results validate the integration of structured movement activities in choral training. Kilpatrick (2020) highlights that movement infused warm ups and rehearsal strategies foster greater physical awareness and emotional engagement among singers. Our findings reinforce this view by demonstrating that movement facilitates not only expressive output but also improved acoustic alignment, particularly in terms of pitch accuracy and blend. Structured gestures that mirror musical phrases such as hand motions representing dynamic changes or breath cues can provide intuitive anchors for singers to internalize musical structures. These movement based strategies offer not only benefits in ensemble synchronization but also in vocal production, encouraging better breath management, alignment, and resonance.

Interdisciplinary Approaches and Ensemble Cohesion

The benefits of interdisciplinary approaches that blend music, dance, and theater become especially salient. Galbreath & Thatcher (2020) advocate for rehearsal models grounded in embodiment and empathy, which allow performers to engage more fully with the emotional and physical dimensions of music. The current study supports this pedagogical orientation by showing that calibrated movement enhances expressivity without compromising ensemble integrity. Encouraging singers to explore expressive movement within stylistically appropriate boundaries may therefore serve as a powerful tool for ensemble development. The inclusion of theatrical or choreographic principles in choral rehearsals particularly in contemporary or genre fusion works can broaden singers' interpretive palettes and support more compelling stage presence.

Spatial Considerations and Staging

The study's findings also carry important implications for rehearsal design and spatial staging. Adaptive spatial configurations such as arc shaped formations or staggered rows can promote greater visual contact and physical alignment among singers, thereby enhancing synchrony. Bland and Cho (2020) report that these configurations not only support better blend and projection but also foster attentiveness and real time interaction among ensemble members. This suggests that movement oriented pedagogy must extend beyond the individual singer to include ensemble wide staging considerations that account for both sonic and visual coherence. The strategic positioning of singers within a performance space, considering variables such as line of sight, proximity, and posture, becomes a key factor in enhancing ensemble cohesion and acoustic output. Furthermore, dynamic staging where singers shift position within a piece can offer both expressive and acoustic advantages when carefully planned.

Genre Specific Applications

Nevertheless, the application of movement enhanced strategies must be tailored to genre and performance context. As Amran (2023) notes, expressive movement is more readily accepted in contemporary and theatrical genres, where emotional communication is foregrounded. In contrast, traditional choral repertoires such as liturgical or classical works may place greater emphasis on restraint and uniformity, requiring a more conservative application of movement. Educators must therefore strike a balance between enhancing expressivity and preserving the stylistic integrity of the repertoire. Rehearsal strategies should be repertoire sensitive, encouraging students to explore

movement possibilities where appropriate, while also developing discipline and control for styles that demand stillness and subtlety. In this way, performers become adept at shifting expressive modalities according to musical context.

Broader Relevance Across Ensemble Types

Beyond choral settings, the insights gained from this study may be extrapolated to other ensemble types. In orchestral contexts, conductor gestures serve as central visual cues that shape timing and interpretation, functioning in ways analogous to the movement based synchronization observed among singers (Kao & Su, 2020). These gestures provide ensemble members with temporal, dynamic, and expressive information, enabling a collective sense of phrasing and musical flow. Similarly, dance music hybrid ensembles, where movement is integral to the artistic expression, benefit from principles of embodied cognition that emphasize the interdependence of physical action and musical communication (Dhahbi et al., 2024). These parallels affirm the broader applicability of body movement as a tool for enhancing ensemble coherence, regardless of specific instrumentation or performance tradition. Further research may investigate how such findings translate across genres, ensemble sizes, and performance environments, particularly in intercultural or multimedia performance settings.

Summary

In conclusion, this study affirms that movement when calibrated and contextually appropriate is a vital asset in choral performance. Slight sway enables singers to synchronize effectively, enriches musical expression, and positively shapes audience perception. Educators and directors are encouraged to adopt pedagogical models that integrate body movement into vocal training, rehearsal design, and performance staging. In doing so, they not only enhance the technical and expressive quality of their ensembles but also align with a growing body of research that views music as a fully embodied, multisensory art form. As performance practice continues to evolve, and as the boundaries between art forms become increasingly fluid, a holistic, movement conscious approach to ensemble training is likely to become a defining feature of 21st century choral pedagogy.

CONCLUSION

This study demonstrates that calibrated body movement, particularly slight and synchronized sway, enhances ensemble coordination and expressivity without compromising acoustic accuracy. The integration of acoustic, perceptual, and motion analysis confirmed that moderate movement supports pitch stability, blend, and mutual alignment among singers, while also enriching audience perception of performance quality.

These findings underscore the importance of adopting movement-aware pedagogies in choral practice. Rather than treating movement as ornamental, educators and conductors can integrate it strategically into rehearsal and staging to strengthen both technical precision and expressive impact. The results also suggest broader applications across ensemble types and genres, encouraging a more embodied and multisensory understanding of music performance.

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