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Laban Effort in Empty-Handed Interactions of Hindustani Dhrupad Vocal Improvisation

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Abstract: Effort, commonly understood as the power of an action toward an intended goal, is acknowledged as an important aspect of music expressivity. Previous studies in Hindustani Dhrupad vocal improvisation, particularly those focusing on manual interactions with imaginary objects, have revealed the intricate connection between effort and various movement and melodic variables. The study employed manual annotations by participants who visually inspected and assessed the amount of effort that such interactions were perceived to require. However, since effort is inherently perceptual and subjective and the way that an observer makes assessments on effort levels remains a non-transparent process, the paper seeks to examine the applicability of the Laban Movement Analysis (LMA) system in this task. For this, it relies on a multi-way analysis of variance (ANOVA) to infer manually annotated (numerical) effort levels from Laban's (categorical) Effort Factors, namely *Weight*, *Flow*, *Time*, and *Space*, for two Dhrupad performances. The results suggest that apart from the Space factor, which was excluded for reasons delineated, a good part of effort's variance can be explained through the remaining three statistically significant Effort Factors, leading to the rejection of the null hypothesis that they are unrelated. By ascertaining this relationship, effort-related melodic aspects in Dhrupad improvisation can be predicted using the three Laban Effort Factors.

Keywords: music technology; motion capture technologies; ethnomusicology; embodied music cognition; oral music traditions; Hindustani Dhrupad music; effort; Laban Movement Analysis; multimodality

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1. Introduction

In recent years, there has been a surge of studies on the concept of effort in music embodiment (Paschalidou 2017, 2022; Antoniadis et al. 2022; Verdugo et al. 2022; Paschalidou et al. 2016; Tanaka 2015; Ward 2013; Antoniadis 2011; Godøy 2009; Bennett et al. 2007; d'Escriván 2006). They are grounded on the acknowledgement of the dynamic properties of movement as innately linked to artistic expressive power (Luciani et al. 2007). Effort seems intricately related to music, whereby the connection between gestures and sound extends beyond simple spatial geometry, such as melographic representation in the 3D Euclidean space (Rahaim 2012), encompassing the exertion of effort against perceived resistive forces (Paschalidou 2017, 2022). The investigation of concepts related to the perception of forces in music has been previously addressed from engineering (De Poli et al. 2009), music theory (Johnson and Larson 2003), and empirical ethnomusicological (Paschalidou 2017, 2022) perspectives. However, effort cannot be simply equated to the objective measure of force as approached in physics, as it is considered a perceptual and subjective measure of power for the reasons explained in the Background section that follows.

In a previous study, effort was examined in the case of Dhrupad vocal music, a subgenre of North Indian Classical music (or Hindustani), in which singers are often observed engaging with melodic ideas by employing and manually interacting with imaginary objects (abbreviated as "MIIOs" in this paper) (Rahaim 2012; Paschalidou 2017). During such instances, performers employ hand gestures akin to sculpting the space around them, which they treat as if it is physically tangible, containing pervasive substances affording various types of interaction (Paschalidou 2024a). Although no real object is involved, on such occasions, singers appear to convey a distinct tactile experience of resistance and effort in relation to the melodic expression. These bodily actions seem to enrich vocalists' ability to conceptualize musical sounds by drawing on familiar motor programs associated with interactions involving real objects. The above observation suggests that distinctive patterns of change in acoustic features of the voice allude to movement qualities of these effortful interactions, which were consequently systematically examined.

The study unveiled associations between effort and diverse movement and melodic characteristics, being most pronounced in pitch-related information of melodic glides, which typically prompt the performer to exert greater physical power. For this, it relied on the premise that effort is essentially a subjective and perceptual aspect that is close to human perception and musical experience and cannot be easily quantified. Therefore, the study drew on manual annotations of effort (and gesture classes) by third-person observations.

Nonetheless, criticism is directed toward manually annotating effort levels. This is because it is a time-consuming and cumbersome method, which renders it impractical in conducting research. Even more importantly, it is because of effort's subjective nature and the absence of a universally accepted ground truth, a concept that will be elaborated in the next section. Since the way an observer makes assessments on perceived effort levels remains non-transparent, it becomes crucial to clarify the criteria used by observers, disambiguating between various underlying aspects. For this reason, the paper seeks to examine the extent of applicability of the Laban Movement Analysis (LMA) system. More specifically it draws on the attempt by Laban to describe main features of human movement in a formalized way without focusing on a particular kind of movement expression, an attempt described by the so-called "Effort Space" in Laban's seminal treatise "Theory of Effort" (Laban and Lawrence 1974). While the dynamic aspects of movement in music have been previously explored from the point of view of the Laban Movement Analysis system (Souza and Garcia 2018; Souza and Freire 2017; Camurri et al. 2000; Yontz 2001; Broughton and Davidson 2014, 2016; Broughton and Stevens 2012; Hamburg and Clair 2004, 2008; Miller 1989), this has never been put into practice in the context of Hindustani vocal music.

For this, a multi-way ANOVA analysis is conducted to test the null hypothesis that effort is unrelated to Laban's *Effort* Factors, namely *Weight*, *Flow*, *Time*, and *Space*. If the null hypothesis is rejected and the assessment of effort through Laban's Effort Factors is proven effective, it may provide researchers with valuable guidance for instructing annotators on how to assess and code effort in a more structured and reliable way. Even more importantly, although this study is confined to the context of Hindustani Dhrupad vocal music, its outcomes may offer a valuable contribution to embodied music cognition endeavor by including oral, and often under-represented, music traditions in music research. Furthermore, by recognizing the significance of multimodal engagement of an audience with a music performance, such as when annotating audio–visual material, it may also highlight embodied ways—for instance, driven by the perception of effort—by which even a novice audience may tap into the complexities of unfamiliar music genres they may have not encountered before. Finally, as such effort-driven embodied interactions have previously been also observed in student–teacher engagement of Hindustani and Carnatak vocal classes (Paschalidou 2024b; Pearson 2016), they also underscore the importance of embodied aspects in music pedagogy, whether in Dhrupad or beyond.

This article is structured as follows: In the first section, the goals of this study are contextualized by outlining some relevant work that illustrates the concept of effort and the Laban Movement Analysis system as well as manual interactions with imaginary objects during Hindustani Dhrupad vocal improvisation. The implicated methods and data are then outlined before presenting the data analysis. The findings are interpreted in the Discussion section, and finally, this paper concludes with some ideas on future work.

2. Background

Historically, music research has emphasized the examination of the compositional significance of a musical work by relying on its symbolic representation, i.e., written notation. However, a noticeable paradigm shift has occurred in recent years, leading to a more comprehensive exploration of music that encompasses both its performative aspect, which refers to the elements of expressive content during musical performances, and its perceptual aspect, which delves into how listeners interpret and experience music. While the initial approach of these two aspects primarily relied on the analysis of the acoustic signal, there has been a growing inclination in more recent years to also highlight the crucial role played by the human body in music cognition.

This evolving interest is deeply rooted in various theories that have emerged over the last three decades under the umbrella term "embodied cognition", with the most recent and radical of which being termed "4E Cognitive Science" or "new science of the mind" (Menary 2010; Chemero 2011). Despite the diversity of these perspectives, they collectively reject the Cartesian separation of mind and body and propose a view that cognitive processes extend beyond the confines of the brain or skull (Noë 2006; Varela et al. 1993; Gallagher 2023). Consequently, they underscore the importance of an agent's physical body and its interaction with the environment in shaping cognitive abilities (Gibson 1986). Building upon this understanding, the human body is now recognized as an essential component of our experiences in music as well (Cox 2016; Johnson 1992), prompting Leman to introduce the term "embodied music cognition" (Leman 2007).

Embodiment plays an especially crucial role in oral music traditions, such as Hindustani (North Indian Classical) and its Dhrupad sub-genre with which this paper deals. In contrast to Eurocentric types of music, which rely heavily on written notation, oral music types rest predominantly upon the direct and experiential transmission of music knowledge from a teacher to a disciple through live demonstration and imitation, with minimal or no dependence on written forms of symbolic representation (Roy 2016; Kohut 1992). In both Hindustani performance and teaching, hand movements play diverse roles, expressing the performer's connection to music, facilitating communication among performers, and engaging with the audience or students (Paschalidou 2017; Pearson 2016; Rahaim 2012; Clayton 2007; Leante 2009; Fatone et al. 2011; Moran 2007).

In Dhrupad improvisation, melodic expression involves smooth, slow glides, with pitch often treated and imagined as a movement in a continuous imaginary "pitch space" that exists between scale steps (van der Meer and Rao 2006). This vocal navigation is mirrored by corresponding hand movements in real space, showcasing a systematic connection between hand movements and melodic patterns (Leante 2009; Clayton 2007). Hindustani singers, as noted in (Rahaim 2012) and personal observations, seem to interact with melodic content using two main approaches: open-handed or closed-handed.

The open-handed mode involves hands effortlessly tracing curves and trajectories in space, providing a simple melographic representation of sound in the real three-dimensional space (Rahaim 2012 and interview testimony). In contrast, the closed-handed mode, with which this paper exclusively deals, comprises powerful movements by which singers appear to manipulate notes through actions such as grasping, holding, extending, restricting, and releasing an object, symbolizing successive phases of intensification and relaxation. These manual interactions with imaginary objects resemble actions of engagement with an (only imagined) object, such as stretching or compressing elastic materials, pulling or pushing heavy objects, etc. (Paschalidou 2022; Rahaim 2012; Fatone et al. 2011). However, these powerful movements do not straightforwardly represent melodic sound in terms of spatial pitch height and do not carry any symbolic meaning either. Instead, they primarily convey dynamic aspects of their acoustic counterpart, imparting proprioceptive sensations of resistance used by singers when manipulating notes as smooth pitch glides. Consequently, effort is manifested through the balance between the perceived resistive force imposed by the imagined object employed by the performer and the force exerted by the performer to overcome it.

According to movement theorist Rudolf Laban (Laban and Lawrence 1974; Laban et al. 1979; von Laban and Ullmann 1988) and other scholars in movement studies (Schiphorst 2009), the expressive content in movement is seen as independent of denotative meanings (Camurri et al. 2004a, 2004b), adding value to a performance (Canazza et al. 2004). It is not solely determined by the type of movement (e.g., punching), but primarily by how it is performed (e.g., light or hard). In other words, it is not merely viewed as a categorical aspect that allows one to classify a gesture into distinct groups, but it is also described in terms of dynamic qualities or variations in the temporal evolution or the dynamic profile of executed natural actions (Niewiadomski et al. 2013; Pierce and Pierce 1989; Leman 2007; Camurri et al. 2003; Mion et al. 2010). This dynamic aspect refers to the forcefulness or power of movement directed toward a distinctive goal, a movement quality often described by the term "effort" in casual usage and linguistically articulated by terms akin to cross-modal metaphors, such as hardness or lightness. The critical aspect of effort lies in the intentionality toward a goal, requiring individuals to fight against and overcome influencing conditions and forces.

Yet, the complex (Dewey 1897), subjective, and perceptual (Steele 2020) nature of effort makes it challenging to simply equate it to force and, hence, to also precisely grasp and define it, rendering its definition in various scientific disciplines, such as physiology, kinesiology, biology, neuroscience, and psychology, inconsistent and imprecise (Massin 2017; Richter and Wright 2014). The goal is perceived as both mental and physical, positioning effort as the interface between the covert (mental) and overt (physical) aspects of the compulsion for movement. Therefore, effort unifies (Maletic 1987) the quantitative and measurable aspect of movement (the physical) with its virtual and qualitative side (the mental) residing in intention. Additionally, given that individuals have varying capacities (intrinsic factors related to a person's fitness or ability) to achieve the same physically and/or mentally demanding goal (extrinsic factors related to the task's difficulty level), effort emerges as a perceptual concept tied to the subjective perception of the intensity of a specific task for a particular individual. Therefore, the assessment of effort commonly hinges on the subjective perception of how challenging the compound task appears to be for the actively involved observer.

Therefore, effort, also in a musical context, is considered in this paper as a compound and perceptual measure that lacks straightforward methods for quantification. This may justify the scarcity of analytical works specifically concentrating on the concept of effort and the deficiency of effective quantitative methods and computational attempts in unequivocally linking the perception of an action's power to objective measures of forces and other related quantitative measures (Piana et al. 2013; Castellano and Mancini 2009; Mazzarino et al. 2009; Chi 1999). Similarly, it may explain the prevailing preference for qualitative methodological approaches (Paschalidou 2017) or indirect quantitative approaches (Paschalidou 2022) in examining its relationship to musical aspects. As effort remains an elusive term due to its complex and perceptual character, it warrants further examination on the way it is manually assessed, which remains non-transparent.

While this paper aligns with the above understanding of effort as a combination of intentionality and physicality, it extends the overt aspect of the goal beyond movement to include the auditory modality of intentionality found in music performance, distinguishing it from previous definitions that primarily focus on movement and kinesiology. Therefore, in this study, effort is regarded as a cross-modal (or amodal) descriptor that combines all three modalities (physical movement, mental impulse, and musical intentionality) that a vocalist can convey and induce and an observer is in the position to perceive and assess. In other words, it is considered as a measure that is visible through human movement, audible in the sound produced, and able to be sensed through proprioception.

In music, effort may be regarded as aligned to "the element of energy and desire, of attraction and repulsion in the movement of music" (Ryan 1991). It mirrors the musical tension within a piece, expressed through patterns of intensification and abatement, eliciting emotional responses (Cox 2016; Krefeld and Waisvisz 1990; Kurth 1922; Lerdahl and

Krumhansl 2007) that are pivotal for both performers and audiences (Olsen and Dean 2016). Performers invest effort to emphasize tension, and audiences must perceive this effort to discern the particularly intense musical passages played by the musician (Vertegaal et al. 1996).

In the realms of movement, dance, choreography, and kinesiology, dance theorist and choreographer Irmgard Bartenieff (Bartenieff and Lewis 1980) considers effort as a subjective measure of expression characterizing the qualities of movement that reflect a person's active or passive stance in confronting or yielding to physical conditions that influence a movement (the driving or limiting forces) meant to accomplish a task. According to dance scholar Vera Maletic (Maletic 1987), effort extends beyond the physical realm of exposing the dynamic qualities of movement and also reflects the inner impulse—the attitude of power in terms of motivation and intentionality—that an individual taps into to achieve a desired goal. Movement scholar Peggy Hackney (Hackney 2003) asserts that it exposes the mover's manner, tone, and energy level, which are often linked with emotion. And finally, movement theorist and pioneer of modern dance Rudolf Laban (1879–1958) regards effort as the foundation of all human body movements (Laban and Lawrence 1974), describing it as the subjective quality that is associated with the forces causing and constraining movement (its dynamics) and reflecting the inner impulse, intention, or source of the movement (von Laban and Ullmann 1988).

In their seminal treatise "Theory of Effort" (Laban and Lawrence 1974), Laban and Lawrence made an extensive attempt to describe the component of *Effort* in a formalized way as a concept that captures the dynamic qualities inherent in movement but without focusing on any particular kind of movement. *Effort* stands as one of the four components (referred to as "*BESS*" for *Body*, *Effort*, *Space*, and *Shape*) and their relationship, which collectively comprise the Laban Movement Analysis (LMA) system, initially developed by Laban (Laban and Lawrence 1974; von Laban and Ullmann 1988) and further expanded upon in (Bartenieff and Lewis 1980). The Laban Movement Analysis system (LMA) has been particularly influential in movement studies, providing a system for the observation, description, notation, interpretation, and classification of human movement, predominantly within the context of Western modern dance choreography (Laban and Lawrence 1974).

Effort is described as comprising a set of four "motion factors", namely *Weight*, *Flow*, *Time*, and *Space*, each of which is characterized by a continuum between two extremes: the "indulging" and "fighting" qualities (Chi 1999; Chi et al. 2000; Camurri et al. 2009). *Weight* reflects the amount of power or the sense of the impact of one's movement, lying between the extreme points of the scale, namely "light" vs. "strong" (in other words, buoyant, delicate, easily overcoming gravity, or marked by decreased pressure vs. powerful, having an impact, and with increased pressure into the movement). *Flow* is considered as an attitude toward bodily tension and control and as a measure of the readiness of a moving person to stop at any moment, which lies in a continuum between two extremities characterized as "free" or "fluid" vs. "bound" or "tight" (in other words, uncontrolled, abandoned, and unable to stop in the course of the movement vs. controlled, restrained, and able to stop). *Time* expresses the sense of duration or urgency conveyed by a movement or sequence of movements, so that an action can be described as "sudden" or "quick" vs. "sustained" (in other words, lingering, leisurely, and indulging in time vs. hurried or urgent) or any other term lying in between. Finally, *Space* refers to the attention to the surroundings or the direction of the movement, with the followed path articulated as lying anywhere in between a "straight" or "direct" vs. a "flexible" or "jerky" trajectory (in other words, single focus, channeled, undeviating, and pointing to a particular spot vs. flexible, meandering, wandering, and multi-focus). By combining the extremes of all the abovementioned units (flexible/direct, light/strong, sustained/quick, and free/bound), we arrive at a set of eight "*Effort Elements*", as illustrated in Figure 1.

Laban Movement Analysis is both a theoretical and experiential system that serves as a practical tool for dancers and choreographers to create intentional and meaningful movement sequences and provides a comprehensive framework for researchers in dance, choreography, kinesiology, and even in the realm of music for observing, verbally articulating, interpreting, and better understanding the intricacies of human movement qualities. Its enduring influence has significantly shaped the way scholars, practitioners, and artists approach the study and creation of movement.

Axes	Indulging Effort	Fighting Effort
Weight	Light	Strong
Flow	Free	Bound
Time	Sustained	Quick
Space	Direct	Flexible

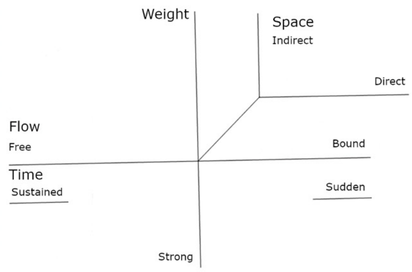


Figure 1. Laban's *Effort Space*, from (Camurri et al. 1999).

The current paper aims to take advantage of the systematic way proposed by Laban for observing, describing, and notating effort in order to enhance and systematize the assessment of effort. Scholars have previously applied Laban's understanding of effort to analyze physical movement in music, which has proven to be instrumental in the advancement of computational methods and research on music embodiment (Chongvattanakij 2016; Hart 2016; Broughton and Davidson 2014, 2016; Broughton and Stevens 2012; Savvidou 2021; Fdili Alaoui et al. 2017; Bernardet et al. 2019; Chambers-Coe 2023; Kikhia et al. 2014; Joko 2020; Camurri et al. 2009; Tan et al. 2020; Campbell et al. 2005; Yontz 2001; Ames 2019; Willoughby 2022; Miller 1989; Hamburg and Clair 2004; Billingham 2001) and for the development of interactive systems in music and dance (Souza and Freire 2017; Souza and Garcia 2018; Françoise et al. 2014).

However, Laban's ideas have limitations when it comes to explicitly quantifying effort measures. First, effort as per Laban is a feature that stands for the description of dynamic movement qualities, while in this work, effort is understood in its common use as the amount of power exerted through an action toward an intended goal. To the best of our knowledge, whether the two approaches—its common understanding and the delineation of effort by Laban—are aligned and associated, has not been examined before and remains to be seen. Additionally, one of the originalities of this paper is attributed to the effective multimodal fusion, whereby raters are expected to make assessments on effort based on the combination of visual (physical movement) and acoustic cues, which has previously been proven significantly associated with effort (Paschalidou 2022). This approach offers a new perspective to Laban's *Effort* Space, whereby the assessment of effort levels relies on a combination of multimodal attributes, as a quality conveyed through hand movements, facial expressions, and sonic qualities of the vocal rendition of the improvisation. Additionally, while the reliability of the Laban Movement Analysis system (not only the effort element) has been previously assessed (Bernardet et al. 2019), to the best of our knowledge, it has never been examined or applied in Hindustani music.

3. Materials and Methods

3.1. Data Collection

The present paper relies on original recordings created specifically for this study during fieldwork conducted in the music school of Zia Fariduddin Dagar in Palaspe, Mumbai, in India between 2010 and 2011. The gathered data encompass interviews, audiovisual materials, and 3D movement data of Dhrupad vocal improvisations featuring, exclusively, disciples of the renowned vocalist Zia Fariduddin Dagar, who were deliberately selected for consistency reasons in terms of gestural resemblance. This methodological choice was made in order to explore the similarities and differences in gestures among musicians who share the same teacher. Despite gestural idiosyncrasy, students also seem to inherit a movement style—similar to inheriting a musical style—that is likely shaped by the unique characteristics of both the musical lineage and the teacher's personal style. Rahaim (2012) introduced the term "paramparic body" to describe the set of bodily dispositions that khayal vocal students acquire over time, following the singing accompanying gestures often performed within their music lineage. This concept builds on Young's idea of the "family body", which refers to the bodily habits family members develop through observation and interaction within their family (Young 2002).

The non-participant video observation analysis reported in this paper relied on the audiovisual material of the vocal improvisation performances by two Dhrupad singers, namely Afzal Hussain in the melodic mode (raga) Jaunpuri and Lakhan Lal Sahu in Malkauns, who were selected from the entire dataset based on the high number of identified MIIO events. Table 1 presents an overview of the collected data.

Table 1. Data overview for vocalists Afzal Hussain and Lakhan Lal Sahu.

	Improvisation	
Vocalists	**Afzal Hussain**	**Lakhan Lal Sahu**
Setup		
Performance details	Melodic mode (raga): Jaunpuri (Rao and Meer 2006a) 45 min total duration	Melodic mode (raga): Malkauns (Rao and Meer 2006b) 33 min total duration
Total MIIO events	90	233

For reasons of ecological validity, all recordings took place in domestic settings, typically in the living rooms where musicians engage in their daily musical activities, with these rooms modified to suit the recording requirements. The participants were informed in advance only about the study's connection to music and movement, without receiving additional details, while the interviews (not covered in this study) typically occurred after the actual performance. The musicians were simply instructed to perform an improvisation in a raga of their choice without further guidance, with the recordings varying in duration based on the musicians' willingness, mood, and recording conditions. The musicians were compensated a small amount per hour for the recording of performances only. To minimize arbitrary reflections that could cause tracking issues with the motion capture technology that was also used to capture upper-body movements, the recordings were conducted in low-lighting conditions using a Sony DCR-SR65 handycam. As a result, all videos were recorded in night mode with only a dim light illuminating the space to facilitate visual contact between the participant and the researcher.

3.2. Method

Due to the exploratory nature of the study, an empirical, sequential mixed methodology was employed. As proposed in (Leman and Godøy 2009), this approach draws on both first- and third-person perspectives for analyzing gestures in music. Our methodology combines qualitative ethnographic methods, specifically video observation analysis of vocal improvisation performances, with quantitative techniques, specifically multi-way ANOVA statistical analysis, applied to the original recordings of audiovisual material. Human movement is an abundant source of information, with different observers often interpreting and assigning diverse meanings to the gestures they observe (Greenhalgh 2019; Klein and Myers 1999). The rationale behind the qualitative approach of the current work, therefore, was to develop a reasonable understanding of the phenomena analyzed and to identify the main categories that could be extracted from the data (Seaman 2008). The qualitative phase of the study took precedence, providing insights and guidance for the subsequent quantitative methods. As the data in qualitative research are essentially less structured than the data generated through quantitative research, the qualitative part of the analysis (video observations) was used first in order to identify and annotate recurrent patterns in the recorded material, specifically the MIIO classes, melodic aspects, effort levels, and Laban Effort Factors. These patterns were then organized, classified, and ultimately used as the "ground truth" for the subsequent quantitative analysis. Specifically, the manual effort annotations served as the "true" response values of the multi-way ANOVA models of the quantitative approach that followed. The methodology is summarized briefly below.

3.2.1. Annotation and Cross-Validation

A single observer visually identified, segmented, and labeled MIIO events. These events were then coded for a number of melodic and movement aspects, including the following:

(a) MIIO classes (categorical), such as stretching, compressing, pulling, pushing-away, collecting, and throwing (categorical descriptors);
(b) Melodic aspects, including melodic movement classes (categorical: ascending, descending, and double), the octave range (categorical: low vs. high), melodic intention (categorical: ascending to stable tonic or not), and pitch interval (numerical = size in cents);
(c) Effort levels (numerical) that each gesture was perceived by the observer to require, in an integer scale of 0-10 (with 10 being the highest).

Results on their inter-relationship have been previously presented in (Paschalidou 2017, 2022). For the current paper the previously annotated *Effort* levels were combined with annotations of the following Laban *Effort* Factors:

(d) Laban *Effort* Factors (categorical): *Weight*, *Flow*, *Space*, and *Time*, comprising three different levels each: low, moderate, and high.

The process of effort annotation entailed evaluating the amount of effort each gesture was perceived to require for each MIIO event, indicative of the effort exerted by the actual performer. Despite the difficulty of assessing effort in the absence of a real, tangible object, an external observer was still expected to be able to make such evaluations through visual observations of the dynamic and kinetic elements of the movement.

To evaluate the reliability of the abovementioned annotation on Laban's *Effort* Factors, the responses were cross-validated (Guest and MacQueen 2012), i.e., compared to responses by other coders who were recruited for this task. The validation of effort levels (rated on an integer scale from 0 to 10, with 10 being the highest) had been previously carried out by two professional dancers/choreographers who were asked to assess the levels of effort that they perceived the performer had committed to the task. They were selected based on their extensive experiences with various dance styles and movement qualities. The cross-annotation of Laban's *Effort* Factors (ordinal scale with responses classified into 3 levels: low, moderate, or high) was conducted by two participants with no specialized background in music or dance who received explicit guidelines to ensure a common understanding of the prescribed annotation criteria as per Laban and to minimize variation in the coding procedure across raters. While cross-annotation did not rely on certified Laban Movement Analysts, it was anticipated that unlike the challenging task of classifying gestures or the advanced skills required for Labanotation (Guest 2005), assessing fundamental movement cues such as *Weight*, *Flow*, *Space*, and *Time* could be easily performed by individuals without specialized expertise.

The subjects were informed beforehand only about the project's focus on examining the correlation between gestures and sound, particularly when singers appeared to interact with an imaginary object. Given the large size of the corpus and the time-consuming nature of the task, only one-third of the samples were presented to the raters, which were strategically chosen to represent the entire performance duration and all types of MIIOs. The raters were allowed multiple viewings of each MIIO instance. Following the original approach of this paper outlined in the Introduction, it was requested by the participants to rely on a combination of multimodal cues for the assessment of the requested annotations, including visual engagement of hand movements and facial expressions and acoustic engagement with sonic qualities. Annotations were conducted on a prepared ANVIL environment, where the raters were asked to input effort levels and one out of the three available levels for each Laban factor corresponding to each MIIO. This set of annotations was then compared to the original codes. The level of agreement among raters was assessed by conducting statistical inter-coder agreement tests to determine if Cohen's kappa value exceeded chance levels (Kipp 2012; Cohen 1960). Hence, although the analysis described in this section was qualitative, a quantitative approach utilizing statistical methods was employed to validate the reliability of the annotations.

3.2.2. Multi-Way Analysis of Variance (ANOVA)

Finally, the cross-validated annotations for both dependent (effort level as discrete numerical, with values between 0 and 10) and independent (Laban *Effort* Factors, as ordinal categorical, each comprising three distinct levels) variables were used in the subsequent statistical analysis. Specifically, they were used in fitting multi-way analysis of variance (ANOVA) models to determine whether there was a statistically significant effect of each of the independent categorical Laban *Effort* Factors (*Weight*, *Flow*, *Time*, and *Space*) on the dependent numerical response variable (effort level), along with whether there were any interaction effects between the independent factors on the response. Hence, both individual and interaction effects were analyzed. Typically, ANOVA is used for continuous (response) variables, but discrete numerical data are also common in practice. The analysis was conducted in R (The R Project for Statistical Computing n.d.).

4. Results

At the outset of the analysis, the audio material for each performer or performance is first introduced, referring to deviations of individual renditions from the theoretical principles of the respective melodic modes (raga) or noteworthy phrases specific to the rendition by each performer. The results of the statistical analysis are presented immediately after.

4.1. Rendition of Melodic Modes (Ragas)

While a melodic mode (raga) can be theoretically defined, variations in mood and nuances in rendition are evident across different music styles and idiosyncratic preferences. The (non-conventional) symbols used in describing the rendition of improvisations and in transcriptions are explained in the Notes on Transcription and Transliteration section of Appendix A.

4.1.1. Afzal Hussain's Rendition of Raga Jaunpuri

Key findings of Afzal Hussain's improvisation in raga Jaunpuri are summarized here.

1. Afzal's rendition of raga Jaunpuri aligns with what is described in (Chordia and Rae 2007). Nevertheless, the seventh degree is treated in a way that better resembles that of Asavari (Bor 1999), as is the tonal hierarchy profile of the raga (Castellano et al. 1984).
2. Except for the slightly lowered seventh degree in the melodic glide between *b*6 and *b*7, peaks in the distributions align with equally tempered intervals.
3. The tonic and fifth are prominent, receiving more focus and time in the performance.
4. The third degree, despite being the second most important note (samvādī), is sparingly used but adheres to typical music theory, where it appears mainly in closing phrases of *b*3-2-1.

5. Contrary to music theory, high melodic activity is observed in the lower part of the middle octave.
6. Sharp peaks on the tonic and fifth, illustrating these sonant and well-defined notes, contrast with flattened distributions around the second, fourth, sixth, and seventh degrees due to smooth pitch glides.
7. Double-sloped melodic glides, characteristic of raga Jaunpuri, abound. They consist of an ascent and a subsequent descent and can be classified as either occurring in the lower part or the upper part of an octave.
8. For melodic glides in the lower part of the octave, emphasis is placed on the highest pitch, while in the upper part of the octave, emphasis varies around the peak distribution of the note while approaching the seventh degree in diverse ways, a significant aspect of Dhrupad performance. Noteworthy pitch glide examples, recurring throughout the improvisation, include the following:
    - Upper part of each octave: .../*b*7~*b*6 in approaching the sixth degree, often resolving to the fifth degree or ascending to the tonic; notably, 5/2′*b*7*b*6 melodic glides, performed in the upper part of the octave, extend beyond the tonic into the next octave.
    - Lower part of the octave: 1/4\2 and 2/5\4 are repeated in succession.

4.1.2. Lakhan Lal Sahu's Rendition of Raga Malkauns

Some important aspects of raga Malkauns, as rendered by Sahu, are summarized below.

1. The fourth degree, while prominent in theory, is used less frequently than the middle tonic.
2. The lower part of the lower octave and the upper octave receive limited attention.
3. Contrary to theoretical expectations, ascents and descents are not very direct. The performer emphasizes specific degrees using chained melodic double-sloped pitch glides, forming stepwise movements toward the targeted pitch, as in approaching the tonic here: *b*6/*b*7*b*6, *b*6/1*b*7, *b*7/1*b*6.
4. As expected, there are numerous *b*7*b*6, 4*b*3, and *b*3\1 glides. In line with the theory, the sixth degree is often approached in ascent through the seventh degree.
5. Both *b*3 and *b*6 are sustained, but—contrary to theory—*b*6 receives even more attention than the fourth degree in the lower octave. In the middle octave, the third degree is also emphasized and sustained.
6. Double-sloped melodic glides abound in the performance; these are most often interlinked within groups of phrases, like the ones already discussed, rather than appearing as isolated melodic phrases.
7. Several gamaks (a technique comprising an oscillation of pitch on a single note or on a series of pitches that are heavily shaken and repeated) were also performed near the end of the improvisation. According to a previous study (Paschalidou 2017), they were accompanied by gestures with similar patterns of intensification and abatement.
8. A high number of melodic phrases appeared in groups of chained double-sloped melodic glides, identified as a/b\c (where b is higher than a and c). As illustrated in Figure 2, they typically convey an impression of initial descent in the first few glides of each group, with the last note (c) being lower than the starting note (a), while the subsequent glides within each group showcase an ascending character, where the last note (c) is higher than the first (a), ultimately reaching the target note of the group (tonic or third). Pitch glides are lengthier at the beginning and gradually shorten as the melody approaches the group's target note. These glides are typically phrased by similar patterns of intensification and abatement (with the intensification part aligning with the ascending part of the pitch glide and the abatement coinciding with the descending part of the glide), as revealed in a previous study (Paschalidou 2017).

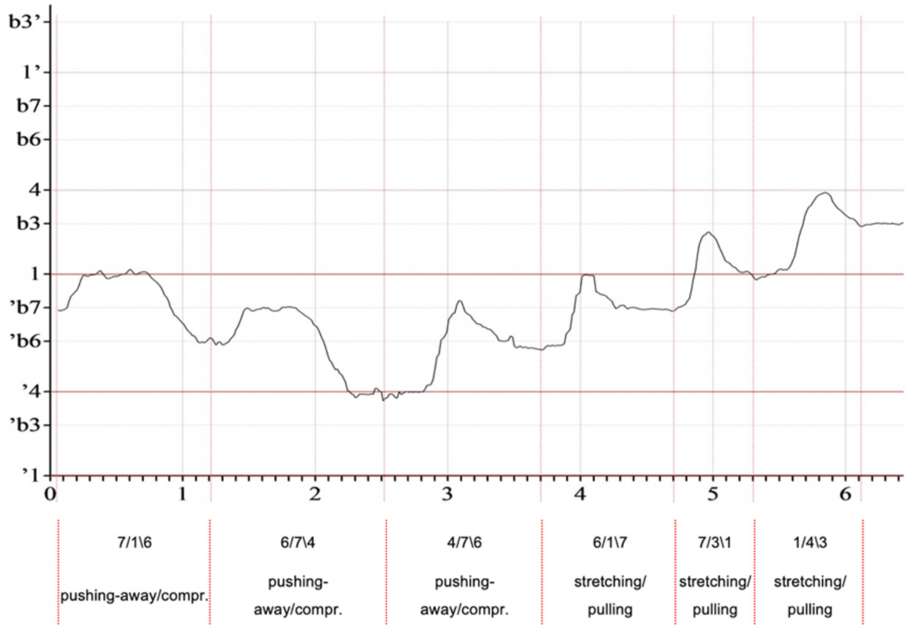


Figure 2. Example of chained pitch-glide group and associated gestures by Lakhan Lal Sahu.

4.2. Cross-Validation of Annotations

From the four factors of Laban's *Effort* continuum, *Space* was omitted from the analysis. This decision was made, as it quickly became apparent that for most instances, *Space* was annotated by the main rater as being single focused or straight. The rationale behind this seems to be rooted in the fact that MIIOs are aligned with salient moments of clear musical intention; hence, they constitute goal-directed gestures performed toward a distinct objective in real space as well. For the numerical values of the *Effort* level (on a scale of 0–10) the inter-coder agreement test of Krippendorff's alpha was computed, which gave a value of 0.81. For the discrete Laban *Effort* Factors, the inter-coder agreement test of Cohen's kappa gave the results shown in Table 2.

Table 2. Cross-validation results for Laban's *Effort* Factors.

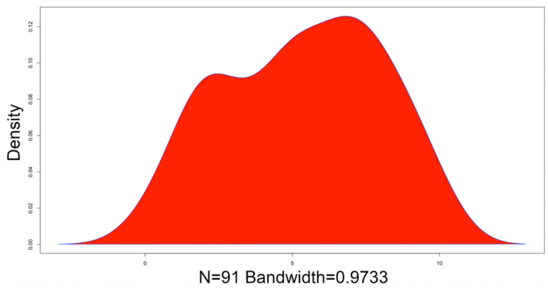
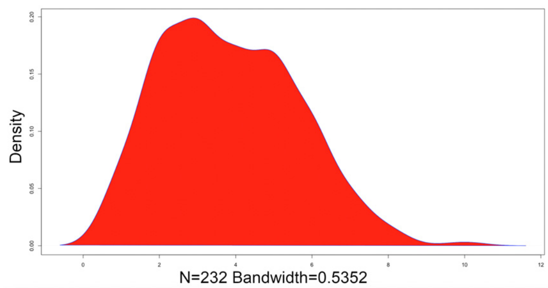
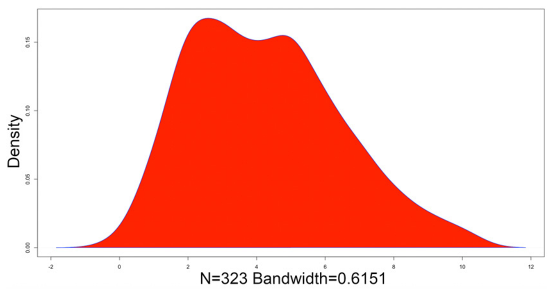
Cohen's Kappa									
	Afzal Hussain (33)			**Lakhan Lal Sahu (116)**			**Entire Dataset (149)**		
3 Annotators	***Weight***	***Flow***	***Time***	***Weight***	***Flow***	***Time***	***Weight***	***Flow***	***Time***
Kappa value	0.803	0.748	0.678	0.865	0.839	0.912	0.851	0.82	0.865
p	3.49×10^{-12}	2.22×10^{-16}	1.85×10^{-8}	0	0	0	0	0	0
Level of agreement	substantial	substantial	substantial	alm. perfect	alm. perfect	alm. perfect	alm. perfect	alm. perfect	alm. perfect

Due to a lack of concrete guidelines for determining a robust threshold for inter-coder agreement, typical values utilized in the social sciences were chosen. Specifically, for the numerical values of the *Effort* level, a reliability level of a $\geq$ 0.8 was set for considering the data as reliable, a $\geq$ 0.667 for tentative conclusions, and lower values to discard the data as unreliable. The alpha value of *Effort* levels significantly exceeded the threshold, indicating a strong level of agreement. For the categorical values of the Laban *Effort* Factors, values of k $\leq$ 0 indicate no agreement, values of 0.01 $\leq$ k $\leq$ 0.20 suggest no or only slight agreement, 0.21 $\leq$ k $\leq$ 0.40 are considered as depicting a fair agreement, 0.41 $\leq$ k $\leq$ 0.60 as moderate, 0.61 $\leq$ k $\leq$ 0.80 as substantial, and 0.81 $\leq$ k $\leq$ 1.00 as almost perfect agreement. For all Laban's *Effort* Factors, Cohen's kappa values significantly exceeded the threshold, indicating a substantial level of agreement or almost perfect agreement among raters. As a result, the original annotations were considered reliable and were used for the multi-way analysis of variance.

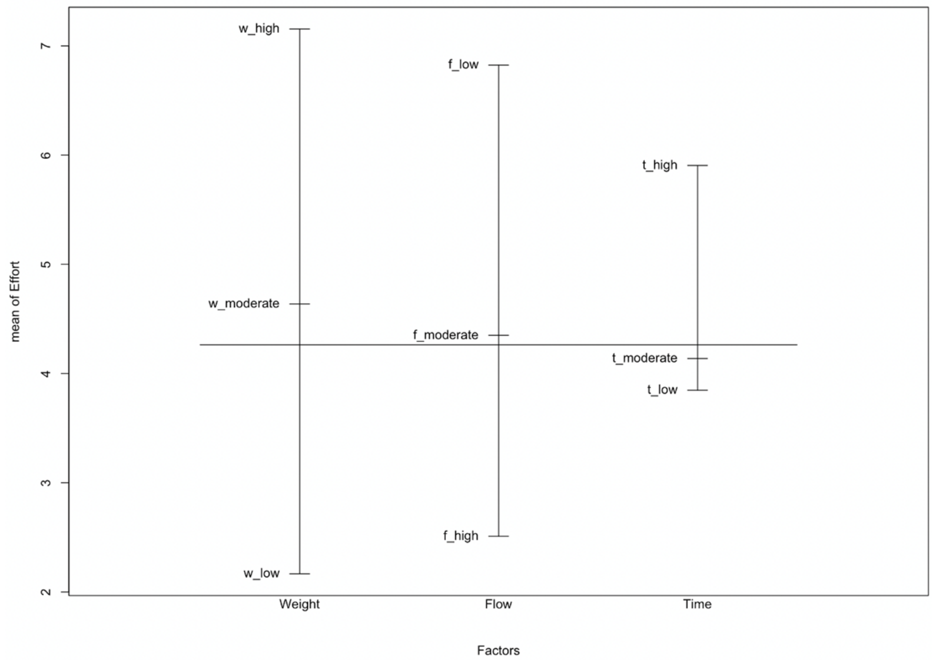
4.3. Descriptive Statistics of Dataset

An overview of *Effort* data is provided in Table 3, illustrating the mean and standard deviation values for the entire dataset but also for each performer separately. It should be noted that these values represent the ratings received for each individual performer. In other words, a rater was requested to first inspect the entire performance and adjust his/her ratings in respect to the *Effort* exertion extremities of the specific performer/performance. Hence, it is a metric that does not allow for the comparison between performers but rather between variables within each performance. The distribution graphs in Table 3 seem to indicate a degree of skewness; however, the significance (low) of deviation from normality in fitting ANOVA models is further inspected in Section 4.4.1.

Table 3. Means and standard deviations for *Effort* levels.

Effort	Mean	Std	Skewness	Kurtosis	Effort Distribution
Afzal Hussain	5.351648	2.676539	−0.14	−1.06	
Lakhan Lal Sahu	3.836207	1.767646	0.40	−0.33	
Total	4.263158	2.170262	0.47	−0.39	

The plot in Figure 3 illustrates the univariate effects of the three Laban *Effort* Factors on *Effort* values, with the levels of each Laban *Effort* Factor (low, moderate, and high) shown along vertical lines and the overall *Effort* response illustrated on the y-axis. The plot reveals that the Laban *Effort* Factors are uniquely distributed in relation to *Effort*.



Weight		***Flow***		***Time***	
w_low:	fine/light	**f_low**	bound/tight	**t_low**	sudden
w_moderate:	moderately heavy	**f_moderate**	medium bound/free	**t_moderate**	moderate in duration
w_high:	firm/heavy	**f_high**	free/loose	**t_high**	sustained

Figure 3. Overview of univariate effects of the three individual levels for each *Effort* Factor on *Effort* values.

4.4. Multi-Way ANOVA Assumption Tests

Before proceeding with the ANOVA, the fundamental assumptions were further tested, namely the normality of the data and residuals, the homogeneity of variances, and individual significant outliers, as well as the independence of the explanatory data. The explanatory data were de facto considered independent, as the methodology resides on explicit instructions given to raters for coding each Laban *Effort* Factor independently of the others and does not include repeated measurements or any other mutually dependent observations; hence, no testing was needed.

4.4.1. Normality

Both the normality of the dependent variable data and of the residuals—considered more important—were examined in order to meet the statistical assumption of normality. For the dependent data (*Effort*), apart from the histograms illustrated in Table 3, skewness and kurtosis statistics were examined and were found to be below the absolute value of 2.00 (skew: 0.47; kurtosis: −0.39 for the entire dataset, with similar absolute values found for each individual performance); hence, the data are normally distributed, and the assumption for normality is not violated. For the residuals, the Q-Q (quantile–quantile) plots for each independent variable (Laban factor) were examined, and deviations were found to be sufficiently limited, permitting the residuals to be treated as normally distributed.

4.4.2. Homogeneity of Variances

A simple visual inspection of density plots seems to indicate a lack of violation in the homogeneity of variances. For a concrete examination, Levene's test was conducted on the interaction of independent variables on effort, indicating relatively unequal variances ($F = 1.69$; $p = 0.031$, with p being under the 0.05 threshold). Although violations of the homogeneity of variances assumption can have a more significant impact than the violation of the normality assumption, especially when there are unequal sample sizes across conditions, it is common practice to still run ANOVA models. Especially given the limited size of the dataset, the extent of the violation was considered effectively minimal and, therefore, acceptable for proceeding with the ANOVA.

4.4.3. Outliers

A low number of isolated outliers were observed in the Q-Q (quantile–quantile) plots, that were not considered as a serious violation of the ANOVA assumption.

4.5. Visualizations of Main and Interaction Effects

The main effects of the *Weight* and *Flow* factors on *Effort* values are visually discernible by the median values, as illustrated by their boxplots in Figure 4. Higher levels of *Weight* as well as *Time* (heavier and prolonged) and lower values of *Flow* (more bound/tight) are more likely associated with higher *Effort* values. However, the impact of the low and moderate levels of *Time* on *Effort* is not discernible, as their median values do not exhibit any differences.

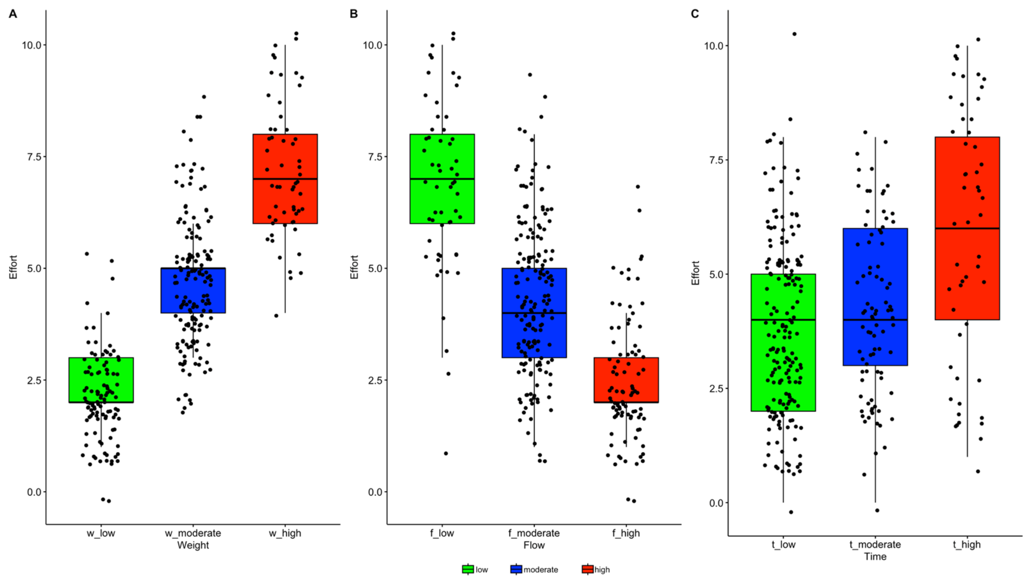
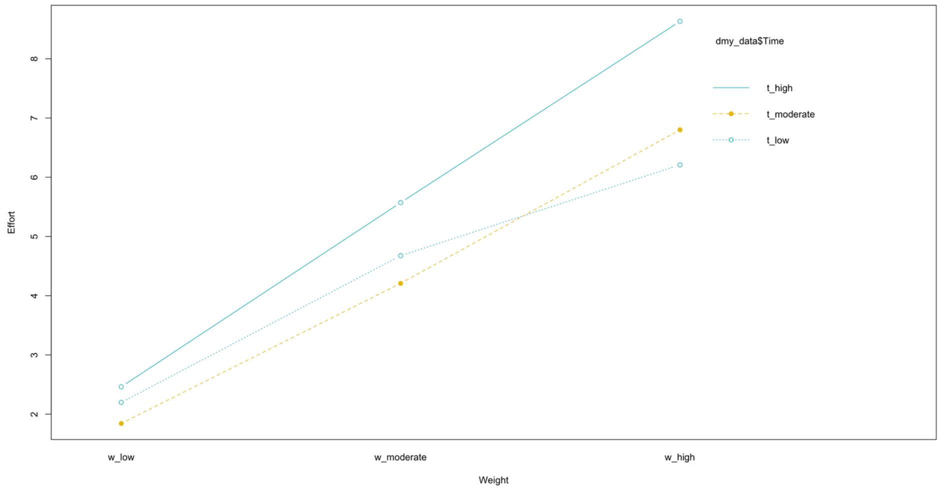


Figure 4. Boxplots for main effects of the three individual Laban *Effort* Factors on *Effort* levels: (**A**) *Weight*, (**B**) *Flow*, and (**C**) *Time*.

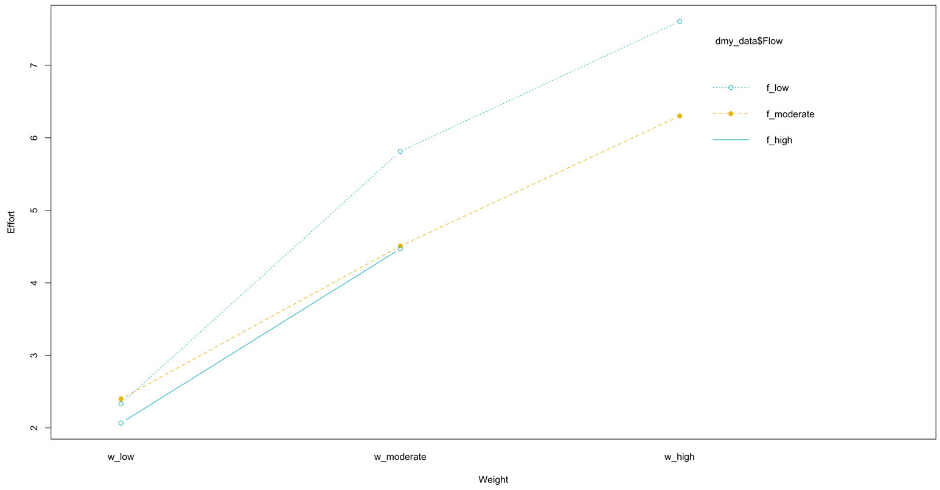
The two-way interaction plots illustrated in Figure 5 indicate a noticeable interaction between *Weight* and the low level of *Time*, followed by a less obvious interaction between *Flow* and—again—the low level of *Time and* between *Weight* and the moderate level of *Flow*. In other words, the effects of *Weight* and *Flow* on *Effort* values depend on Time, especially for quick MIIOs (t_low), and that of *Weight* depends on the moderate level of *Flow* (relatively bound).

As illustrated by the interaction plot in Figure 6, the most pronounced *Weight*Time* interaction effect is visually observed for the low level of *Flow* (level designated as 1 in Figure 6), in other words, for the case of bound/tight gestures.

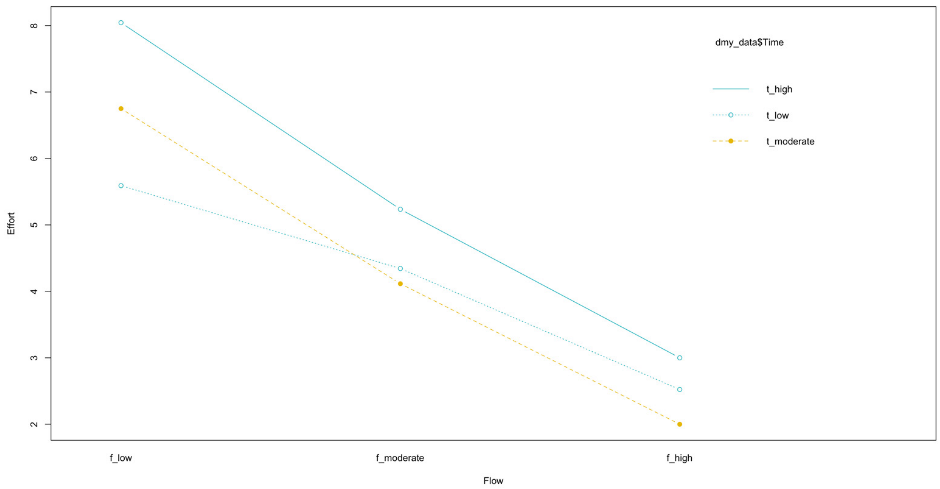
The combined effect of all three *Effort* Factors on *Effort* values can be examined through the boxplots in Figure 7. The small dataset makes it hard to visually deduce safe conclusions for all combinations of *Effort* Factors and levels. However, from the boxplots, it is possible to deduce a clear effect on *Effort* by the interaction between *Weight* and *Time*, while their dependence on *Flow* is less prominent, taking into account the non-discernible median values of the *Flow* (color) boxplots, in a similar way to Figure 4C.



(**a**)



(**b**)



(**c**)

Figure 5. (**a**–**c**) Two-way interaction plots for all combinations of independent variables (Laban *Effort* Factors) on *Effort* levels: *Weight*, *Flow*, and *Time*.

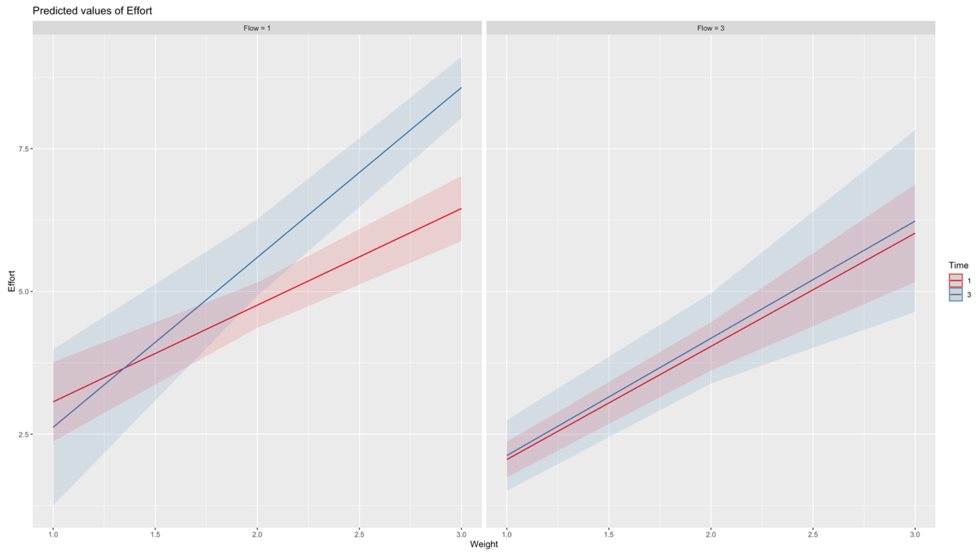
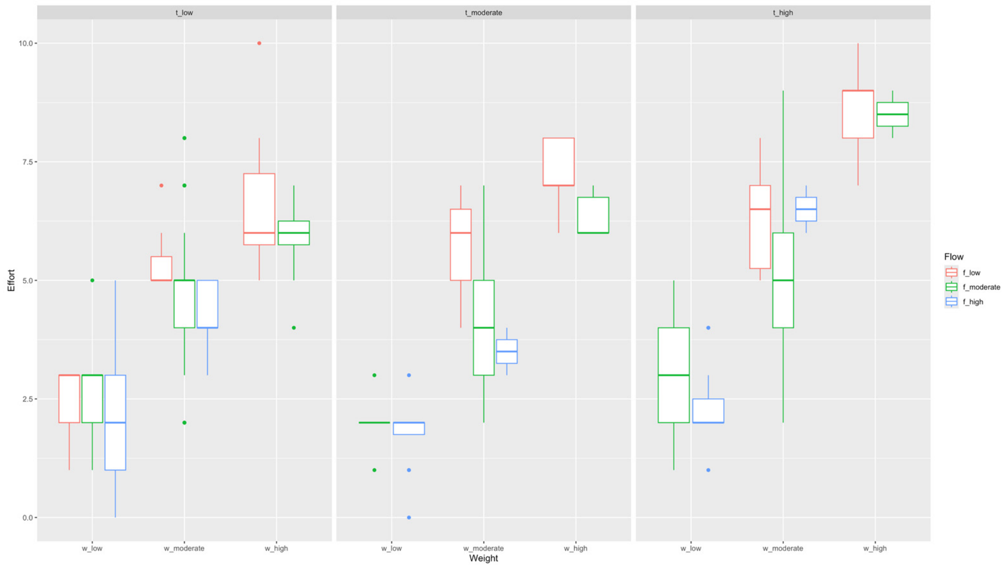


Figure 6. Interaction plots, revealing an interaction effect of *Weight*Time* on *Effort*, *only for the lower level of Flow*.



(**a**) (**b**) (**c**)

Figure 7. Boxplots for the combined effect of all three Laban *Effort* Factors, namely (**a**) *Weight*, (**b**) *Flow*, and (**c**) *Time*.

4.6. Multi-Way ANOVA Model Fit

All possible combinations of independent factors (with or without interactions) in the explanation of the (dependent) *Effort* variable were examined in developing an ANOVA model, and the accuracies of model fit were compared. The selection of the model relied on a trial-and-error process in search of the highest goodness of fit, based on the Akaike Information Criterion (AIC) and the Bayes Information Criterion (BIC) methods, leading to the ANOVA formula *Effort* ~ *Weight* + *Flow* + *Time* + *Weight*Time*. This model comprises all three statistically significant Laban factors as well as the interaction between *Weight* and *Time*. It explains a statistically significant and substantial proportion of variance (R2 = 0.72, F(10, 312) = 81.51, $p < 0.001$, and adj. R2 = 0.71). The model's intercept, corresponding to *Weight* = w_low, *Flow* = f_low, and *Time* = t_low, is at 3.08 (95% CI [2.54, 3.61], t(312) = 11.35, and $p < 0.001$). The three-way interaction term (*Weight*Flow*Time*) was not rendered significant.

4.7. Multi-Way ANOVA Model Effect Size

As can be deduced from Table 4, the fitted three-way ANOVA model suggests the following:

- The main effect of *Weight* is statistically significant and large (F(2, 312) = 364.77, $p < 0.001$; Eta2 (partial) = 0.70, 95% CI [0.66, 1.00]);
- The main effect of *Flow* is statistically significant and medium (F(2, 312) = 16.54, $p < 0.001$; Eta2 (partial) = 0.10, 95% CI [0.05, 1.00]);
- The main effect of *Time* is statistically significant and medium (F(2, 312) = 18.47, $p < 0.001$; Eta2 (partial) = 0.11, 95% CI [0.06, 1.00]);
- The interaction between *Weight* and *Time* is statistically significant and small (F(4, 312) = 3.87, $p = 0.004$; Eta2 (partial) = 0.05, 95% CI [9.08×10^{-3}, 1.00]).

Table 4. Summary of effects of *Weight*, *Flow*, and *Time* on *Effort* level.

						Measures of Effect						
Term	**df**	**Sumsq**	**Meansq**	**Statistic**	***p* Value ***	**Etasq**	**Partial. etasq**	**Omegasq**	**Partial. omegasq**	**Epsilonsq**	**Cohens.f**	**Power**
Weight	2	981.722	490.861	364.775	$<2 \times 10^{-16}$ *** <0.001	0.647	0.700	0.645	0.693	0.646	1.529	1.000
Flow	2	44.510	22.255	16.538	1.49×10^{-7} *** <0.001	0.029	0.096	0.028	0.088	0.028	0.326	1.000
Time	2	49.697	24.849	18.466	2.63×10^{-8} *** <0.001	0.033	0.106	0.031	0.098	0.031	0.344	1.000
Weight/Time	3	20.858	5.214	3.875	0.00435 **	0.014	0.047	0.010	0.034	0.010	0.223	0.902
Residuals	312	419.845	1.346									

* Signif. codes: 0, "***"; 0.001, "**"; 0.01, "*"; 0.05, "."; 0.1, " "; 1.

Effect sizes were labeled following the recommendations in (Field 2013).

More specifically, within this model, the following was found:

- The effect of moderate *Weight* [relatively strong] is statistically significant and positive (beta = 2.30, 95% CI [1.89, 2.72], t(312) = 10.98, and $p < 0.001$; Std. beta = 1.06, 95% CI [0.87, 1.25]).
- The effect of high *Weight* [strong] is statistically significant and positive (beta = 3.49, 95% CI [2.88, 4.11], t(312) = 11.15, and $p < 0.001$; Std. beta = 1.61, 95% CI [1.33, 1.89]).
- The effect of moderate *Flow* [relatively bound] is statistically significant and negative (beta = −0.73, 95% CI [−1.16, −0.29], t(312) = −3.27, and $p = 0.001$; Std. beta = −0.33, 95% CI [−0.54, −0.13]).
- The effect of high *Flow* [bound] is statistically significant and negative (beta = −0.99, 95% CI [−1.54, −0.45], t(312) = −3.61, and $p < 0.001$; Std. beta = −0.46, 95% CI [−0.71, −0.21]).
- The effect of high *Weight* [strong] × high Time [sustained] is statistically significant and positive (beta = 1.80, 95% CI [0.80, 2.80], t(312) = 3.55, and $p < 0.001$; Std. beta = 0.83, 95% CI [0.37, 1.29]).
- All other cases of combinations were found to be statistically non-significant.

Standardized parameters were obtained by fitting the model on a standardized version of the dataset. The 95% confidence intervals (CIs) and *p*-values were computed using a Wald t-distribution approximation.

4.8. Post Hoc ANOVA Tests

Post hoc multiple comparisons of means—Tukey's honestly significant difference test (HSD)—were performed to determine which mean ratings were significantly different from one another (at $p < 0.05$). This 95% family-wise confidence test revealed a number of pairs that showed statistical significance, which are illustrated by confidence intervals that do not cross the zero point (where the difference between the means is equal to zero) on the graph in Figure 8. These results match the hypothesis test results in Table 4.

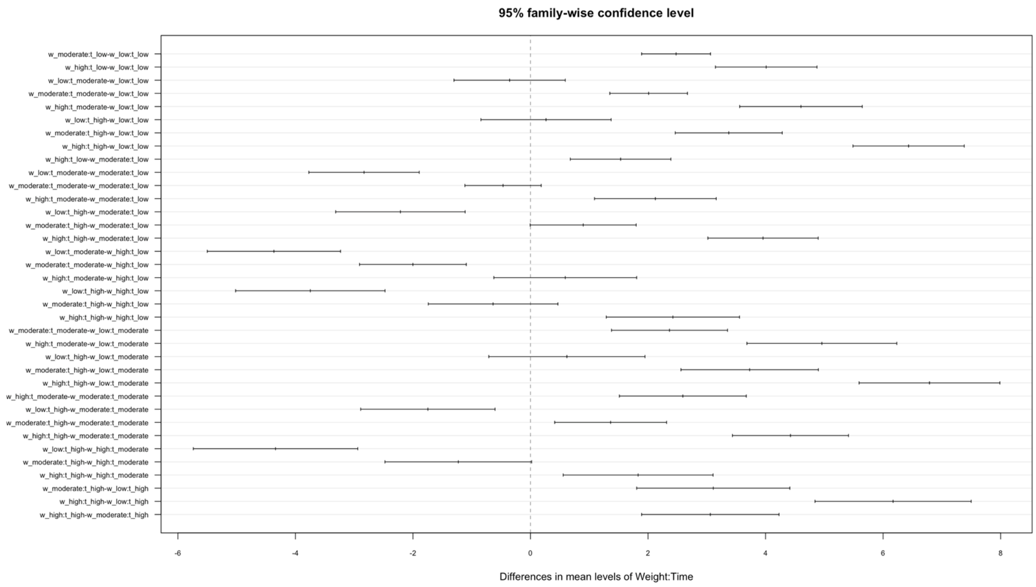


Figure 8. Tukey's honestly significant difference test (hsd) illustrating post hoc multiple comparisons of means.

5. Discussion

Despite a recent trend in musicology and ethnomusicology in gesture–sound studies that emphasizes more experiential and embodied perspectives in music perception, much of the research has traditionally prioritized geometric aspects and structural representations, like shapes and textures (Küssner and Leech-Wilkinson 2014; Godøy et al. 2006), giving less emphasis to the dynamic aspects of gesture that draw upon ecological psychology and affordance theory (Gibson 1979). Godøy (2006, 2009) proposed expanding the notion of the "sonorous object" by Schaeffer (1966) to include effort and energy transfer, yet experimental research exploring these ideas has been somewhat limited, with only recent growth in the literature (Paschalidou 2022; Pearson and Pouw 2022; Paschalidou et al. 2016).

To the best of our knowledge, this is the first time the LMA system has been applied to Hindustani singing gestures, and it comprises one of the few computational approaches to applying LMA in music performance. The reliability of the Laban Movement Analysis (LMA) system has been previously assessed primarily through the visual perception of gestures not specific to music (Bernardet et al. 2019). However, to the best of our knowledge, it had not been studied before in the context of music performance or as a compound concept encompassing modalities beyond silhouette movement, such as the acoustic. Broadly speaking, while LMA has predominantly drawn the attention of dance and gesture studies, even computational approaches (Aristidou et al. 2015), its application in music performance has been less explored (Willoughby 2022), although it has been employed in various interactive sonification applications (Giomi 2020; Souza and Garcia 2018; Françoise et al. 2014).

The results of the multi-way ANOVA test indicate the rejection of the null hypothesis, suggesting a significant relationship between effort levels, as evaluated by one rater and cross-validated by two others, and Laban's *Effort* Factors. Specifically, the inclusion of the *Weight*:*Time* interaction in the model, alongside the main effects of the three Laban factors (*Weight*, *Flow*, and *Time*), explains a statistically significant and substantial proportion of the variance in effort levels.

In simpler terms, the findings suggest that *Effort* as defined by Laban—i.e., a carrier of the dynamic qualities of movement—effectively aligns with the actual exertion of effort as a measure of power, which can, hence, be explained through the four *Effort* Factors. Additionally, even though Laban primarily focuses on movement in his effort descriptions, utilizing all modalities for the assessment of the Laban *Effort* Factors has still provided a substantial explanation of variance in effort levels. This validates the decision to follow the original approach of the proposed methodology and reinforces the concept that effort is a complex multimodal—or even amodal—measure, necessitating the utilization of various sensory modalities for its accurate assessment.

The results extend the findings of previous works (Paschalidou 2022, 2024a; Paschalidou et al. 2016) on effort–voice–gesture relationships by proposing a more systematic and transparent approach to manually annotate effort through third-person observations. This approach refines the subjective perception of effort into concrete and more easily identifiable gestural qualities (*Weight*, *Flow*, and *Time*, with *Space* being excluded for the reasons previously explained).

6. Conclusions

A multitude of interesting future work suggestions and interventions can be drawn from this work. Given the findings of a previous study (Paschalidou 2022) that ascertained the strong relationship between effort and raga-specific melodic features, it also makes sense to suggest that by relying on the three Laban Effort Factors, it is possible to predict or infer raga-specific melodic features. For instance, it has been previously suggested (Paschalidou 2022) that the degree of effort exerted by the vocalist's body in the case of the performance by Afzal Hussain in raga Jaunpuri is linked to the following:

(a) The pitch range of the octave, specifically the highest note reached during the ascending part of the melodic glide (upper or lower section of an octave);
(b) The melodic intention of ascending to or toward the tonic in the subsequent melodic progression;
(c) The interval of the (ascending part of the) melodic movement;
(d) The morphological analogy, with ascending and descending melodic glides corresponding to increased vs. decreased effort, respectively.

Drawing from these clear-cut associations between effort levels and melodic features, Laban's Effort Factors offer a systematic and more reliable way of assessing these values. As a result, the findings of this study lead to the further proposition that incorporating Laban Effort Factors for body movement may prove valuable in enhancing the success of raga classification tasks, as previously attempted (Paschalidou and Miliaresi 2023) with other multimodal features.

However, it is also essential to recognize the project's limitations. A key aspect of this work was the collection of original audio–visual material and manual annotations in the field. While this approach enhances ecological validity, it also introduces challenges and limitations. The integration of qualitative and quantitative methods with real performance has introduced a delicate trade-off between an ethnomusicological perspective and a systematic analysis typical of controlled, repeatable experiments. By adopting an ethnographic approach, which involved recording typical performances rather than structured experiments with repeated stimuli, there was a high risk of obtaining limited data or missing relevant gestures entirely. The analysis and findings are currently confined to only two performers/performances, who displayed a high number of MIIO occurrences, and only three raters, emphasizing that they mirror the expressive choices of a chosen group of musicians and annotators within a single music lineage. Incorporating a greater number of participating musicians and diverse music genres will enhance the reliability of the conclusions drawn regarding the validity of effort assessments and their correlation with melodic features specific to each music genre. Finally, the possibility of disambiguating between various modalities in the assessment of effort presents an intriguing, although challenging, next step. The resulting small dataset makes it difficult to draw broad conclusions applicable to the Dagar music lineage of Dhrupad and other Hindustani music lineages. Larger datasets with multiple recordings of the same raga for each performer would support more systematic comparisons across performers, performances, and ragas.

However, ethical considerations regarding the cost of the research and accessibility of such funding should also be raised at this point.

Finally, in this study, effort levels have been manually annotated and treated as the "ground truth" in the analysis. However, our future goal is to enable the indirect computation of effort levels by relying on LMA Effort Factors, which are simpler to compute (Camurri 2017; Fdili Alaoui et al. 2017; Piana et al. 2013, 2016). This approach could help reduce the reliance on cumbersome manual annotations.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was approved by the Departmental Ethics Committee of Durham University's Department of Music in 2010.

Informed Consent Statement: Written informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Publicly available datasets were analyzed in this study. These data can be found here (last access: 29 February 2024): https://collections.durham.ac.uk/files/r10p096691p; https://collections.durham.ac.uk/files/r12b88qc178.

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Conflicts of Interest: The author declares no conflicts of interest.

Appendix A. Notes on Transcription and Transliteration

The "/" symbol represents a smooth ascending melodic glide, establishing a seamless connection between adjacent notes. Similarly, the "\" symbol signifies a gentle descent. Symbols such as "-/" and "-\" indicate stepwise ascent and descent, respectively, implying melodic progressions where notes are not smoothly connected through glides. The "^" symbol is used to emphasize the pitch preceding it. Lastly, the "-" symbol symbolizes emphasis and prolongation of the note preceding it.

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