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Research article

Reflections on *Bharatanatyam* and Neuroscience. A Dance Studies Perspective

SLOKA IYENGAR
The American Museum of Natural History
New York, USA
slokaiyengar2014@gmail.com

MANSI THAKKAR
Navrachna University, Vasna Bhayli Road
Vadodara, Gujarat, India
thakkarmansi1234@gmail.com

CHANDANA R. HOSUR
Navrachna University, Vasna Bhayli Road
Vadodara, Gujarat, India
chandanarhosur@gmail.com

DRASHTI MEHTA
Center for Neural Sci (Ret), NYU
New York, USA
mehtadrashti6@gmail.com

VIBHAKAR KOTAK
Center for Neural Sci (Ret), NYU
New York, USA
vck1@nyu.edu

†Corresponding author: slokaiyengar2014@gmail.com

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Abstract
Building on recent interest in the convergence of arts and sciences, we propose specific areas of intersection between the disciplines of Bharatanatyam, a classical Indian dance, and neuroscience. We present personal reflections by practitioners of both disciplines and propose that Bharatanatyam can be used to understand and explain brain functioning and that neuroscience can help analyze the dancing Bharatanatyam brain. We explore conceptual areas of convergence between the two fields as well as specific points of connection using language acquisition, rhythm, music, and cognition as examples. We conjecture that Bharatanatyam training and practice support long-term neuronal plasticity in various parts of the brain, including but not limited to the hippocampus, motor, premotor cortex, and the cerebellum. The beginning of the study of the intersection between these disciplines will pave the way for additional allied fields of rich thinking, exploration and potentially, therapy.

Key words: Bharatanatyam, Neuroscience, Subjective Reflections, Dance Studies

An early introduction to the tradition of Bharatanatyam and the discipline it requires presented with many benefits in adulthood

Bharatanatyam has been part of my life for as long as I can remember. After a minimum of 7 years studying this dance form, the student ascends the stage in a formal debut performance called the "*Arangetram*." The expectation is that this debut performance is the beginning of a dancer's dance-life and that individuals would go on to perfect their skill, keep practicing, performing, and teaching. As a young girl and woman in India, Bharatanatyam was critical in fostering a positive body image and ensuring that I was physically active in a world where many of the sports activities were reserved for boys and men. I also learned how to work with other people, how to observe my gurus when they gave feedback to others, and how to receive feedback. After my *Arangetram*, I learned the process behind choreography, basics of dance pedagogy, the theoretical aspects of Bharatanatyam, and had the opportunity to watch countless shows. This was an education in seeing the choreography process in class, the preparations backstage, and finally, the actual show. Speaking to the versatility of Bharatanatyam, my colleagues and I presented many non-traditional pieces, one of them being "The Life of Jesus Christ."

When I came to the United States to pursue my graduate work in neuroscience, I realized all the ways dance affected me. Unbeknownst to me, the dance education of my childhood and adolescence was a perfect complement to the neuroscience education I was getting in graduate school. For example, the process of watching performances (which is highly encouraged in Bharatanatyam pedagogy) is rooted in the involvement of mirror neurons. Mirror neurons are located in the premotor cortex, supplementary motor areas, primary somatosensory cortex, and the inferior parietal cortex (Acharya, 2012) and are critical for procedural and observational learning and imitation (Wolf, 2000). Over the years, I encountered numerous scientists who were practitioners of some kind of artistic endeavor as well. Dancing as an adult neuroscientist gave me better insight into the deep knowledge inherent in these fields and their intersection.

The goal of this paper is to present and draw on our personal experiences as practitioners of Bharatanatyam and neuroscience and draw insights that show how Bharatanatyam and neuroscience may have more points of convergences than perhaps meet the eye. Specifically, we highlight subjective experiences from performers who have had first-hand knowledge in the theory and practice of Bharatanatyam and present the basic neuroscience education supporting these views.

However, there are several points we wish to clarify at the offset. We do not aim to provide an exhaustive report on the convergence of Bharatanatyam and neuroscience as it is outside the scope of this publication. While we provide several citations, we admittedly do not cite every author and group that has provided value to the field. Not providing citations is here an acknowledgement that we are skimming the surface of a huge field and body of work. Many of the topics we present here about Bharatanatyam (e.g., rhythm, musicality) are aspects of many other kinds and genres of dance (Brown, 2008). However, we propose that the narrative, story-telling, and devotional aspects of Indian classical dance forms such as Bharatanatyam may have specific and unique neural correlates. Again, the aim of this paper is not to provide a comparative overview on the different kinds of dance forms or the brain structures involved that are similar and dissimilar. Bharatanatyam was undoubtedly affected by the cultural upheavals over the centuries in India; hence, while we realize the involvement of culture in Bharatanatyam, our aim is not to analyze the role of cultural context in Bharatanatyam practice and performance. Many other experts have contributed to this line of thinking (Kumar, 2011). While in the future, targeted experiments to understand how the brain enables each aspect of Bharatanatyam and how Bharatanatyam affects the brain of the performer and the audience, we do not present any

experimental data. Despite these caveats, this paper is one of the first that meshes together two seemingly disparate fields cohesively, gives proposals for future studies both empirical and experimental, speaks to the universal nature of dance and science, and finally, provides personal reflections in the background of theoretical support and underpinning.

We propose that thinking about the intersection of Bharatanatyam and neuroscience could be pertinent for a variety of fields: making a case for arts and science (specifically, neuroscience) education in schools and colleges and the idea that embracing the arts can enable a more complete and holistic society. Finally, we suggest that Bharatanatyam can help us better understand the complex functioning of the brain, and the study of neuroscience can help understand why and how Bharatanatyam has the effects it does on peoples, cultures, and societies. Our hope is that this publication supports future work into this rich field of thinking, exploration, and ideally, some aspect of behavioral therapy.

Bharatanatyam is one of the oldest classical Indian dance forms

Bharatanatyam originated in the temples of South India more than 2,000 years ago and consists of many elements that bear resemblance to the sculptures and inscriptions found in temples (Rajkumar, 2020). The *Natya Shastra* is a detailed handbook that was written between the 5th century BCE and the 8th century CE (Lidova, 2014), and covers various aspects of the dramatic and performing arts including but not limited to music, rhythm, aesthetics, theater, and movement. This treatise is still used to guide students of Bharatanatyam and deeply influences the way the dance form is practiced and performed. For example, many aspects related to staging, costuming, and makeup were put forward in the *Natya Shastra* and are still used today (Lidova, 2014). The political and cultural upheaval of the 17th century in India affected Bharatanatyam as well, and the dance form as it is viewed and practiced now in mainstream circles has undergone significant changes as compared to its initial version (Rajkumar, 2020).

A fascinating aspect of dance is the dichotomy between stillness and movement and, pertinent to this paper, how the brain perceives this difference appropriately to create and complete the aesthetic picture. Bharatanatyam consists of intricate variations in facial expressions, hand mudras and physical gestures. These movements and gestures are accompanied by classical based *Carnatic* vocal singing and ascending and descending rhythms played on a percussive instrument such as the *mridgangam* and/or *tabla*. Bharatanatyam can be thought as a vocabulary of hand, feet movements, gestures, and emotion that are interspersed with music and rhythm. In line with the musicality of Bharatanatyam, dancers are also encouraged to learn music and music theory. With an emphasis on communicating *bhava* (the state of mind leading to feeling, emotion, or mood), *rasa* (the aesthetic flavor that results from *bhava*) and storytelling, I think of Bharatanatyam as a language to communicate a story or an abstract idea to the audience.

The neurosciences are a collection of related disciplines, all with the aim of understanding how the central and peripheral nervous systems function in pathology and physiology

The last several decades have seen an intense interest in the neurosciences, thanks to the variety of tools and techniques available to study various aspects of the brain. The neurosciences are a truly unique field and aim to explain the various functions of the brain and, by extension, the body. A neuroscientist can study one or more avenues including neuroanatomy; neurophysiology; molecular and cellular neurobiology; and pathology of the central and peripheral nervous system. In the last several years, many initiatives (Allen Institute for Brain Science & The BRAIN Initiative 2012) have been launched to understand how the brain makes us thinking, feeling, and sentient creatures. While the study of neuroscience is rich and rewarding, so is its dissemination. Given the breadth of the discipline, there are many unique ways to explain neuroscience as well. Acting on

this insight, I have composed several pieces that use Bharatanatyam to explain neuroscience: in one, I depict the movement of ions through the neuronal membrane during an action potential, and in another, I describe the process of neuronal migration. Since action potentials are the output of excitatory and inhibitory neurons in the brain and hence the mechanism of all that we do, think, and feel, it is incredibly exciting to me to think that there is a tangible, performative link between my Bharatanatyam and neuroscience!

The myriad of physical movements and mental acuity in Bharatanatyam necessitate sensorimotor coordination, neurotransmitters and modulator mechanisms and engages learning and memory constantly and in real-time as well as fine motor performance in conjunction with continuous sensory feedback.

There are many conceptual and philosophical points of intersection between Bharatanatyam and neuroscience

Seemingly disparate at first glance, we propose that neuroscience and Bharatanatyam have several points of conceptual intersection. The first is the wide appeal of the disciplines. Although having originated in South India, Bharatanatyam is the most popular form of Indian classical dance currently with practitioners residing in almost every part of the world. In an analogous fashion, the study of neuroscience is conducted all over the world, and scientists of different sub-disciplines come together to share findings during scientific conferences.

Both neuroscience and Bharatanatyam build on a long lineage of work. In Bharatanatyam, the *guru* or teacher (and the *guru's guru*, in effect) along with books like the *Natya Shastra* guide students in their dance journey. This academic genealogy is found in the neurosciences as well, where students study under a mentor for several years before setting up their independent research practice. Both disciplines build upon an already-existing body of work to add to the knowledge of the field. Additionally, the role of teaching and giving back through teaching is common in both neuroscience and Bharatanatyam. One might wonder how any innovation is possible when there is a body of work that is literally centuries old. In fact, when I was in college, reading the prescribed textbooks gave me a distinct impression that everything that could be discovered scientifically, already had been. It was only during my graduate work that I realized how much there is still to be explored. Similarly, while Bharatanatyam is admittedly an ancient dance form, there are practitioners all over the world using this art form to tell diverse, contemporary stories. While the subject of creativity is still not fully understood and involves (among other regions) a set of cortical structures called the default mode network (Beaty, 2020), we believe that the topic of creativity and innovation in Bharatanatyam and neuroscience warrants further attention. Specifically, there may be similarities in brain activity when conceptualizing a novel experiment or hypothesis vs. choreographing a set of movements or developing an idea to depict through dance.

We believe that both Bharatanatyam and neuroscience are ways of understanding the truth around us and give us a way to understand the truth that may be ever-changing and dependent on context. An example of the contextual nature of neuroscience is the example of neurogenesis. While the thinking for a long time was that the adult human brain cannot produce new neurons (Kumar, 2019), newer techniques and studies have proved otherwise (Kumar, 2019). The complete details surrounding adult neurogenesis are not known, but there is still plenty of room for research and investigation (Kumar, 2019). Speaking to the conceptual convergence, Bharatanatyam could provide an alternative way of thinking of the brain, perhaps in the form of a securely and carefully choreographed ensemble? Can we think of neuronal assemblies as working together like dancers would in a performance?

The practice of Bharatanatyam and neuroscience requires similar skills and attributes (SI)

Some attributes that are common to the study of Bharatanatyam and neuroscience are perseverance and resilience, both of which, of course, are difficult to quantify. I was unable to continue dance during graduate school and had a break of almost seven years. While I had concerns about returning to Bharatanatyam after such a long time, it seemed that my body remembered many, if not most of the *adavus* (steps) and *jatis* (combinations of steps). The long-term effects of Bharatanatyam on the brain are not fully studied, but based on studies on other dance forms (Rehfeld, 2017), we can expect long-term, synaptic reorganization including strengthening in several parts of the brain as a result of the prolonged, intense, and consistent training program. These changes in neuronal structure and function are perhaps even more pronounced in the developing brain (D'Souza, 2018), so the specific role of Bharatanatyam during child development needs to be studied systematically owing to the critical stages of learning via sensory perceptions during the first decade after birth.

Language acquisition is complicated by itself, and perhaps even more so when learning and performing a Bharatanatyam piece (SI)

I recently started re-taking Sanskrit language lessons as a way to supplement my dance education, and I was struck by the musicality of the language and the structure inherent in its grammar. However, when I dance to a Sanskrit poem, I am able to (hopefully) depict its beauty and nuance without knowing the grammatical structure of the verse. Thinking of language acquisition, it is not fully known how the brain de-emphasizes grammar while listening to the poem for dance, vs. appreciates its order and structure when learning it as a formal language.

As a dance form that originated in South India, many compositions that are used for the traditional dance pieces are written in South Indian languages e.g., Tamil, Telegu, and Kannada. In consequence, the study of Bharatanatyam requires the dancer to acquire at least a rudimentary understanding of a few different languages. In addition, given the poetic structure of the pieces we dance to, an aesthetic understanding and appreciation of the text is critical. Learning what and how to emote to a certain song or poetry necessitates learning the language and the vocabulary of the written word to some level. Language acquisition is a complex process; imaging studies have parsed out areas in the brain (called the "Wernicke's area") and its sub-structures that are critical for language reception, word recognition, associating words with other information, and production of language (Ardilla, 2016). An additional structure called the insula plays a role in coordinating all these language systems (id.). The brain also puts together additional linguistic factors such as syntax, sentence comprehension, semantics, and phonology to help bring a nuanced and complete understanding of language (Sakai, 2005). The neuronal mechanisms for interpreting language set to music for dance are not understood; however, we can hypothesize the role of cortical plasticity, not dissimilar to what has been observed in response to the acquisition of a second language (id.).

In many pieces, the dancer has the job of interpreting not only the literal meaning, the imagery that it carries, and the derived, expanded meaning, but the musicality as well. In Bharatanatyam, the meaning is highlighted in the context of "*sthayi bhava,"* the stable, pervading emotion and the "*sancari bhava*" or the fleeting emotions that appear in quick succession. I wonder how the brain interprets language and its nuances to emote such delicate and refined expressions. The hand gestures in Bharatanatyam are a catalog of vocabulary not unlike words. How might semiotics (the study of signs) apply to Bharatanatyam and what are the brain structures involved? The cultural nature of semiotics and the specificity (Yu, 2013) align with the gestures used in Bharatanatyam in that they have cultural underpinnings. Since using signs is an indirect form of language that does not require auditory cues, we would expect the visual areas to be involved. To this point, since music is such an important part of the dance form, an additional question that can

be explored is if different structures of the brain are involved when a piece of text is read as compared to when it is set to music. Additionally, what is happening in the brain when dancers are using their bodies to depict a certain poem's message or narrative? The storytelling in Bharatanatyam does not seem to be completely tied to a verbal element because it is possible to understand the narrative to some extent without knowing the language. Could Bharatanatyam give us clues to explore linguistic questions from those of pure narration? The neurological correlates of movement set to a poem would involve motor and premotor structures; however, the exact nature of this activation is not known and could be further explored.

The study of music and Bharatanatyam are closely linked (CRH)

I started perusing lessons in *Carnatic* music at the age of ten. Initially it was difficult, but I was raised in a musical environment, which helped me acquire skills such as *shruti shuddham* (pitch perfection), *taala* (rhythm or beat), reading notation in *swaras* (notes), understanding that each beat has sense of *laya* (pace or speed of rhythm) to it. My education included the teaching that in order to sing for any composition, a basic understanding of the language was necessary to ensure correct pronunciation and intonation. My music must faithfully convey the composer's meaning and underlying sentiments. Repetition is key - as a student I was repeatedly made to sing the phrases so as to memorize them within a short time span. What helped the memorization was that with the intonation of every *taala*, its *jaathi* (melodic classification) and the *raga*, I would create a picture of the relationship between the musical element and the emotion I felt. Listening to other musicians was an important part of my training as well. The tremendous ability that music has to affect and manipulate emotions and the brain is undeniable, and yet largely inexplicable. Now that I am a student of neuroscience, I think about the link between melody and mood. Also, what exact effects did grow up in a musical household have on my brain? I grew up learning that musicians are very good at math, probably because all these *swara* and *taala* patterns involve calculation and manipulation.

Carnatic music consists of two main elements: *raga*, the melodic-scalic component of the music, and *taaḷa*, the rhythmic cycle. These two come together to create *bhava*. I sing for Bharatanatyam dancers, and just like dancers, musicians when on stage have to be highly attentive and sharp listeners to observe and analyze the dynamics that the music contains. *Carnatic* music and Bharatanatyam are closely linked, and I wonder if the *rasa* in Bharatanatyam aligns in the brain to the *ragas* of the music in terms of what is being affected in the brain. While typically many aspects of Bharatanatyam are scripted, there is a role of improvisation in Carnatic music, and I wonder what brain structures and processes help live improvisation.

I am also intensely curious about the role of passive listening. It is known that many parts of the brain are activated by passive listening of melody rhythmic sequences. In a study where non-musicians passively listened to musical rhythms, activation was observed in several areas in the premotor cortex and the cerebellum (Sharma,2018), the latter, we would expect to be important to coordinate movement with rhythm. The precise nature of brain activation when listening to *Carnatic* music by practitioners and non-practitioners is not known and could be further investigated.

The melodic framework in Carnatic music has been developed in the structure of "*ragas*." There are 72 *melakartha ragas* (or parent *ragas*) that are formed by different types of *swara sthayis* or note pitches. These main *ragas* give rise to *Janaka ragas*, which means that the possibility of melody in Carnatic music is endless! Students of Carnatic music are taught the four components of *raga*: *nada* (the sound that is audible to human ears), *swara*, scale (ascending-aarohanam and descending-avarohanam), and *gamaka* (vocal articulation or instrumental manipulation). I wonder how, in a live show, the singer's brain keeps all these aspects in mind, and at the same time, pays attention to

the dancer to improvise if necessary? Perhaps this happens at a sub-conscious level. What experimental paradigm might allow us to investigate and answer these questions? Singing and listening to music gives me so much pleasure, and I would love to explore the neuronal correlates of pleasure and surprise when listening to certain melodies and the role of culture at the same time (Libeto, 2020). I can hypothesize that neurotransmitters such as oxytocin, dopamine as well serotonin have a role to play in the mood-enhancing as well as self-rewarding effects of music (Sutoo, 2004).

Given the intense practice that Bharatanatyam entails, there are many long-lasting effects on cognition (MT and DM)

While most students start learning Bharatanatyam around age five or so, I started late, at around twelve years of age. It seemed that other students in my class were more flexible, whereas it took me a year to internalize the basic position of Bharatanatyam called *Araimandi*, a position that requires balance of midline posture and core muscles. As a student of neuroscience, I now know the role of the cerebellum in maintaining this difficult posture. The symmetry of steps is maintained by sensory feedback which the brain receives from muscles and joints of our limbs. Postures and symmetry of steps develop over time, and I can imagine that in advanced practitioners of Bharatanatyam, the corticospinal tract must enable voluntary movements, the cerebellum helps learn and coordinate new movements and the basal ganglia helps maintain body posture while in movement.

As I passed through several years of studying Bharatanatyam, the level of difficulty also increased, and the cognitive capability of my brain was challenged. Bharatanatyam has a set repertoire called "*margam*," which consists of pieces that are progressively more challenging in terms of skill of executing rhythm, emotions, and pure stamina. The dance form has three aspects: *nritta* ("pure" percussive pieces), *nritya* (a combination of percussion and emotion), and *natya* (dramaturgy). I felt that understanding the theory behind these aspects gave me a sound basis when I tried to learn new items. There are so many things to keep in mind when dancing – remembering the *adavu*, its pattern and sequence, the *taala, bhava*, facial expressions, and ultimately, being able to communicate all this to an audience. I wonder what kinds of attentional process allows the brain to manage all this so effectively, and what happens in the brains of the audience members who are watching me. Do their brains capture each aspect separately, or do they get the holistic picture that allows them to appreciate the dance and the story?

Many studies that have investigated the neurological correlates of dance suggest that long-term dance training changes both gray and white matter structures (Karpati, 2015); however, the nature of these adaptations in Bharatanatyam is not known. I wonder also about the changes in the brain in an individual who started learning young as compared to those who may have started later, or in adulthood. Also, what is the exact nature of long-term changes in cognition and short as well as long-term plasticity? I can hypothesize that the hippocampus and the para-hippocampal regions must be involved, as these are the structure where memories are encoded, stored and recalled, but beyond this, systematic studies are necessary.

I am also curious about the interplay between cognition and emotion (Erickson,2003). As a dance form where communicating emotion is key, what brain structures may be involved in remembering a feeling or mood that is evoked by the music, and then being able to perform it on stage? My training in Bharatanatyam makes the learning of other dance styles comparatively easy; I practice other dance forms as well and have found the classical training of Bharatanatyam uniquely helpful. Might there be overlapping areas of cognition and sensensorimotor synchronization between the dance forms? Another aspect is the effect of long-term Bharatanatyam training: one study (Burzynska, 2017) looked at dancers and non-dancers, and examined a variety of imaging

parameters, cognitive assessment, and objective measures of dance skill. They found changes in connectivity in the Action Observation Network (AON) in dancers as compared to non-dancers. The AON consists of structures in the occipito-temporal, parietal, and premotor cortex of the brain and is critical for the visual interpretation of actions (Urghen, 2020). We hypothesize that trained Bharatanatyam dancers will show many of the same changes in the AON; these findings will potentially form the case for using Bharatanatyam as a source of therapy, reward, and well-being. These changes in the AON must be long-lived; having taken a break from dance for two years, I found that it was relatively easy to get back into the routine of dancing again, suggesting that storage of Bharatanatyam information in the brain must have facilitated such comfort. Another aspect I have always wondered about is how thinking about dance is different, neurologically speaking, from the act of dancing itself. I know that many athletes prepare by thinking of the game and what it entails, and I have found that works for me in Bharatanatyam as well. When I am thinking of dancing, I would expect my motor cortex to be activated, though at a threshold lower than what is necessary to generate movement, suggesting altered properties of neurons. Could Bharatanatyam be used as a therapy to rehabilitate people after major disorders like a stroke or memory loss?

Conclusions

In this paper, by interspersing our personal experiences of learning and practicing Bharatanatyam and neuroscience, we propose that the practice and performance of Bharatanatyam is associated with unique activation of discrete areas of the brain and the input-output of these neurons into a well-defined performance. While the disciplines are disparate in many ways, we believe that they both provide insights of understanding and perceiving the world around us. Pursuing this convergence will lead to enrichment of culture and the acceptance of different forms of wisdom: rational vs. empirical; scientific vs. artistic. A systematic study of the innovation inherent in two seemingly disparate disciplines will help us better understand the process of creativity. We can also envision employing Bharatanatyam in neurological and psychiatric disorders for stress relief as a potential de-stressor such as in the present crisis, and for using Bharatanatyam and other dance forms in furthering education.

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Conflicts of interest

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