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Neural Correlates of Emotional Expression and Cognitive Processes in Odissi Dance: Implications for Real-Time Biofeedback Systems

Saanvi Tripathy

Podar ORT
Email: *saanvitrip080[at]gmail.com*

Abstract: ***This study explores the neural and cognitive mechanisms behind emotional expression in Odissi, one of India's oldest classical dance forms. Drawing from neuroaesthetics, cognitive neuroscience, and artificial intelligence (AI), the research examines how dance integrates memory, attention, emotion, and motor skills. Using AI-assisted tools—OpenPose for motion tracking, Google Teachable Machine for facial emotion recognition, and Python's NLTK/VADER for sentiment analysis—we analyzed real-time performances of 20 participants, including expert Odissi dancers and non-dancers as controls. Expert dancers demonstrated significantly higher motor-emotional coordination, with 87.2% accuracy in facial emotion recognition and distinct movement patterns closely aligned with emotional intent. In contrast, control participants showed lower synchronization and expressive accuracy. This is the first study to apply AI-based analysis to Odissi for real-time performance feedback. The findings highlight how specific movement and expression patterns are linked to underlying cognitive and emotional processing. These insights lay the groundwork for real-time biofeedback systems, with potential applications in dance pedagogy, cognitive training, and therapeutic rehabilitation.***

Keywords: Odissi dance, neuroaesthetics, AI motion analysis, emotional expression, cognitive feedback, movement and cognition

1. Introduction

Background Information

The intricate relationship between neural function and aesthetic experience has drawn growing interest within cognitive neuroscience, particularly through the emerging field of neuroaesthetics. Semir Zeki's pioneering research (Zeki, 1999) identified how brain regions such as the orbito-frontal cortex and primary visual cortex (V1) contribute to aesthetic judgment and visual-emotional processing. Zeki's work suggests that complex aesthetic forms, including dance, activate integrated emotional and cognitive networks—a hypothesis this study applies specifically to the classical Indian dance form *Odissi*.

Odissi, with over 500 years of continuous tradition, offers a unique lens into embodied cognition and emotional expression. Its defining elements—*Chowkh* (a grounded square stance), *Tribhangi* (a three-part body bend), and *mudras*(symbolic hand gestures)—differ significantly from the linear, often symmetrical movement vocabularies of many Western dance forms. These stylized postures require advanced motor coordination while conveying intricate emotional narratives (rasa), making *Odissi* an ideal subject for studying how movement and affect are interwoven in the brain.

Recent advances in AI-based motion tracking and facial emotion recognition have made it possible to analyze these expressive elements with greater precision. However, few studies have applied these tools to traditional Indian dance, leaving a gap in understanding how cultural movement forms engage cognitive-emotional systems—an area this research addresses.

Research Gap

While much research has been done on Western forms of dance and their neurological impact, Indian classical dance forms remain underexplored in the neuroscientific domain. There is a lack of studies that use real-time AI tools to analyze the integration of motor patterns with emotional expression in Odissi.

2. Research Questions and Objectives

Primary Question:

How are neural and cognitive processes reflected in the motion and emotional expressions of Odissi dancers?

Secondary Questions:

1) How do expert and non-expert dancers differ in their motor-emotional synchrony?
2) Can AI-driven systems provide reliable real-time biofeedback to support dance training and rehabilitation?

Objectives:

1) Analyze motion and emotional patterns using AI.
2) Compare cognitive-emotional integration between different participant groups.
3) Develop a framework for real-time biofeedback systems for dance training.

Significance

This study contributes to the intersection of neuroscience, performing arts, and artificial intelligence. It bridges traditional art forms and modern scientific inquiry, creating new opportunities for therapeutic applications, advanced training tools, and greater cross-disciplinary understanding of embodied cognition.

3. Literature Review

Neuroscience of Dance

Dance engages multiple brain systems involved in memory, attention, motor coordination, and emotional processing. Neuroimaging techniques such as fMRI, EEG, and MEG have shown that expert dancers exhibit heightened activation in the Action Observation Network (AON), particularly in regions like the premotor cortex and inferior parietal lobule, when performing or observing familiar movement sequences. These findings align with the theory of *embodied simulation*, where mirror neurons activate even during passive observation, creating a neural link between action and perception.

While most neuroscientific studies have focused on Western dance or martial arts, emerging research on Indian classical dance forms is beginning to bridge this gap. For instance, fMRI studies on *Bharatanatyam* (Brown et al., 2015) reveal increased activation in AON regions, supporting the idea that culturally specific dance forms also recruit complex motor-emotional circuits. Given the shared use of symbolic gestures (*mudras*) and non-linear postures, similar neural engagement is likely in *Odissi*, especially during the performance of *Tribhangi*, which requires simultaneous activation of upper, middle, and lower body segments.

Furthermore, long-term dance training has been linked to improvements in psychomotor speed, executive function, and sensorimotor integration. These benefits are particularly significant for aging populations or individuals with neurodegenerative conditions such as Parkinson's or Alzheimer's disease (BMC Neuroscience, 2023).

Biofeedback Systems

Modern biofeedback systems leverage motion tracking, real-time sentiment analysis, and facial recognition to deliver automated, AI-powered insights. Systems like OpenPose and Move AI track joint and limb movement with high accuracy. Simultaneously, emotion recognition platforms like Google Teachable Machine provide insight into real-time affective states. These tools are revolutionizing dance analysis, making it data-driven and personalised .

4. Conclusion of Review

Current literature underscores the strong neural basis of dance and the integral role of emotion in movement, supported by activation in networks such as the Action Observation Network (AON), cerebellum, and orbitofrontal cortex. Yet, a significant gap remains in applying these neuroscientific and AI-driven insights to Indian classical dance forms—especially *Odissi*—which uniquely combine complex motor sequences with expressive emotional storytelling.

This gap is particularly critical for *Odissi*, where emotional nuance is conveyed through highly codified *mudras* and body postures like *Tribhangi*, requiring fine-grained motion analysis and facial emotion recognition. AI-integrated systems capable of real-time feedback could provide both pedagogical and therapeutic value, enabling a deeper understanding of how cognitive and emotional processes are embodied in traditional forms.

A potential hypothesis emerging from this review is: *Odissi dancers exhibit higher AON activation and greater emotion-movement synchronization compared to non-dancers during expressive performance*. Future research integrating neuroimaging with AI-based motion and affective tracking can help test this, advancing both cognitive neuroscience and the digital documentation of cultural heritage.

5. Methods

Study Design

This observational study integrates AI-assisted analysis of Odissi performances, combining motion tracking, facial emotion recognition, and text-based sentiment analysis to assess cognitive and emotional components in real time.

Participant Groups

- Group A: Professional Odissi dancers (5+ years experience)
- Group B: Non-dancers
- Group C: Individuals with prior exposure to Odissi (audience members, students)

Data Collection Techniques

- Motion Tracking: OpenPose used for full-body joint tracking (https://github.com/CMU-Perceptual-Computing-Lab/openpose)
- Emotion Recognition: Google Teachable Machine for facial analysis (https://teachablemachine.withgoogle.com)
- Sentiment Analysis: Python's NLTK/VADER used for analyzing verbal feedback and performance annotations (https://www.nltk.org)

Data Analysis Methods

- Statistical tools: ANOVA, correlation analysis
- Visualization: Matplotlib, Seaborn for graphical representation of motion and emotion data

Ethical Considerations

All participants in the study provided informed consent prior to data collection, ensuring they fully understood the purpose, methods, and potential applications of the research. The study adhered to strict ethical guidelines, with all personal data anonymized and securely stored to protect participant privacy. Data collection involved non-invasive techniques and posed minimal risk to individuals. Participation was entirely voluntary, with the option to withdraw at any stage without consequence. Furthermore, the study received approval from the relevant Institutional Ethics Board, confirming that it met established standards for research involving human subjects.

6. Results

Findings

Group A dancers exhibited more consistent joint coordination and smoother movement trajectories, particularly during complex poses such as Tribhangi and Chowkh. Facial emotion recognition data indicated significantly higher accuracy among these expert dancers, with their expressions aligning closely with the intended *Rasa* (emotional themes) of the performance. Additionally, sentiment analysis of post-

performance narratives revealed a stronger emotional resonance and more positive affective responses to performances by professional dancers compared to those by non-dancers or less experienced participants.

Comparison Across Groups

Parameter	Group A (Dancers)	Group B (Non-Dancers)	Group C (Exposed)
Emotion Recognition (%)	87.20%	65.40%	72.50%
Joint Coordination Score	High	Low	Medium
Sentiment Polarity Score	0.81	0.62	0.73

Statistical Significance

- ANOVA tests confirmed significant group differences ($p < 0.05$) in both motion smoothness and emotional expression accuracy.

7. Discussion

Interpretation of Results

The findings support the hypothesis that experienced Odissi dancers demonstrate a higher level of motor-emotional integration compared to non-dancers and less experienced individuals. This was evident in their ability to execute complex poses like Tribhangi and Chowkh with greater consistency and coordination, as captured through motion tracking data. Moreover, the emotional intent embedded in their performances was more accurately recognized by AI-based facial emotion analysis, indicating a stronger alignment between movement and affective expression.

Sentiment analysis of post-performance narratives further reinforced these results, showing that audiences responded more positively and with greater emotional depth to the performances of professional dancers. This suggests that the combination of technical mastery and emotional clarity in expert Odissi dancers not only enhances expressive authenticity but also deepens the audience's aesthetic and emotional experience. Together, these outcomes underline the role of long-term embodied practice in refining both the physical and affective dimensions of performance.

Applications of Biofeedback

- AI-driven feedback systems can help dancers monitor emotional accuracy and motion efficiency in real time.
- In therapeutic settings, similar systems can aid motor rehabilitation and emotional expression therapy.

8. Comparison to Prior Research

This study reinforces existing findings from Western dance neuroscience while introducing new cultural contexts via Odissi. It aligns with previous work on the action observation network and expands it to incorporate real-time emotional measurement.

9. Limitations

- Small sample size limits generalizability
- AI tools had occasional recognition errors under poor lighting
- Cultural nuances in emotional expression may challenge standard emotion classifiers

10. Future Research Directions

- Use of multimodal deep learning models for better emotional detection
- Cross-cultural comparison between different classical dance forms
- Longitudinal studies tracking neuroplastic changes from dance training

11. Conclusion

11.1 Summary of Key Findings

Odissi dancers demonstrate heightened integration of cognitive and emotional processes, evident in their precise motor coordination and nuanced emotional expression. What sets Odissi apart from many Western dance forms is its unique structure—combining symbolic *mudras*, asymmetrical postures like *Tribhangi*, and a narrative-driven approach to performance that demands simultaneous physical, cognitive, and emotional articulation. This intricate fusion highlights the dance form's deeply embodied nature and cultural specificity.

AI tools such as motion tracking and facial emotion recognition effectively captured these elements in real time, revealing distinct performance signatures in expert dancers that were markedly different from those of control participants. These results underscore Odissi's potential as a rich model for studying embodied cognition and emotion through both scientific and artistic lenses.

11.2 Implications

- These findings support the development of AI-based biofeedback systems tailored to culturally specific art forms like *Odissi*. Such systems hold promise for real-time performance enhancement, neuroadaptive learning, and personalized dance training.
- Beyond the artistic domain, the study opens new avenues in clinical and therapeutic settings—particularly in cognitive rehabilitation, emotional regulation, and sensorimotor therapy—where structured expressive movement can be used as a tool for neural engagement and healing.

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