

# The Neuroscience of Dance: The Effect of Individual versus Group Dance on Mirror Neuron System Engagement

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## ABSTRACT

The neuroscience of dance has been widely explored in recent scientific research, using neuroimaging technologies to monitor the brain activity of dancers and dance observers. Dance involves multiple brain systems and large amounts of learning, directly relating to the roles of mirror neurons in imitation and observation. However, there is a scarcity of research directly comparing the effects of individual and group dance on mirror neuron-related activity. This narrative review compares the effects of individual observational learning and group synchrony in dance on mirror neuron-related activity. Data was collected in the form of a literature review, using keywords to search for relevant articles. The selected articles were either electroencephalography (EEG) or functional magnetic resonance imaging (fMRI) studies focused on action observation networks. The results revealed that both individual and group dance promoted activation in the premotor cortex, the supplementary motor area, the inferior parietal lobule, and the inferior frontal gyrus. While few studies directly compared individual and group dance, the results show that group synchrony may be associated with greater engagement of mirror neuron-related regions, resulting in potential increased functional connectivity and neural synchrony in these regions. The results of this study could be applied to dance or art therapy to utilize the positive benefits of interpersonal synchrony in group therapies.

## INTRODUCTION

Originally identified in the premotor cortex of macaque monkeys, mirror neurons have been found to fire both when an individual performs an action and when they observe the same action performed by another. Essentially, mirror neurons are neurons that activate during both action execution and action observation (Cook et al., 2014). Since their initial discovery, mirror neurons

have generated significant debate regarding their functional role in humans. While early research emphasized their contribution to basic action understanding, later studies reveal the mirror neuron system (MNS) is associated with processes such as learning, imitation, prediction, and social coordination that

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support action understanding, as well as interpersonal synchrony. The functions of the MNS are still being explored, and there are various hypotheses for the involvement of mirror neurons in complex actions (Cattaneo et al., 2009). Since mirror neuron activity in humans cannot be directly measured, this study refers to activation in mirror-neuron related regions rather than firing of individual neurons.

Dance is an ideal model for studying various aspects of the brain, including the mirror neuron system. Dance is a distinctive combination of motor and musical activity, and carries the neural benefits of both. Unlike many sports, which focus on goal-directed movements, dance prioritizes expressive and complex motion. Compared to musical arts, which emphasize fine motor control and rhythm, dance requires full-body integration, continuous hand-eye coordination, and rhythmic synchrony. Dancers must constantly adjust movement in response to music and space, as well as other individuals. Dance requires individuals to connect with themselves and to others, which has been associated with increased neural synchrony from dancers and increasing dance's effects on the brain (Basso et al., 2021). This combination makes dance uniquely suited for examining the brain in various contexts.

Additionally, dance fuses music, movement, and memory all together in one activity, in a highly complex manner, and its engagement of multiple brain systems promotes increased functional connectivity between motor, sensory, and cognitive regions (Brown et al., 2005). Due to this fusion, dance is able to involve several systems in our brain, such as the auditory system, motor system, visual system, and more. Audiovisual stimulation has been associated with greater activation in mirror neuron-related regions than simply auditory stimulation (Tanaka, 2021), and dance involves multiple forms of stimuli. Dance's valuable neurological effects have marked it as a prime candidate for anti-neurodegenerative therapy, and are still being explored as such (Kattenstroth, 2010).

Lastly, an immense aspect of dance is learning. Dancers frequently learn by watching others, immediately translating observed movements into motor output. Whether it is learning a new move, style, or routine, dancers must constantly pick up and adapt to new choreography. Dance's strong connection to learning makes the art form an effective model for studying neural mechanisms involved in skill acquisition and coordination. The learning demands of dance further reinforce the relevance of mirror neuron-related systems, which support the translation of observed actions into executed movements.

As a whole, dance is an extremely stimulating and neurally demanding activity, engaging multiple neural systems simultaneously. Learning and executing dance involves large amounts of imitation and coordination, directly connecting it to the mirror neuron system's main functions. Specifically considering the mirror neuron system's involvement in action observation and execution, dance is a very efficient tool to study the MNS, as it engages these aspects and more.

This study will focus on four brain regions which are commonly associated with mirror neurons. Firstly, the premotor cortex. The premotor cortex (PMC) is responsible for planning out movement based on internal and external cues. The neurons in the premotor cortex have shown increased activity in response to a cue that triggers movement, as opposed to the actual movement itself. Studies have also shown that

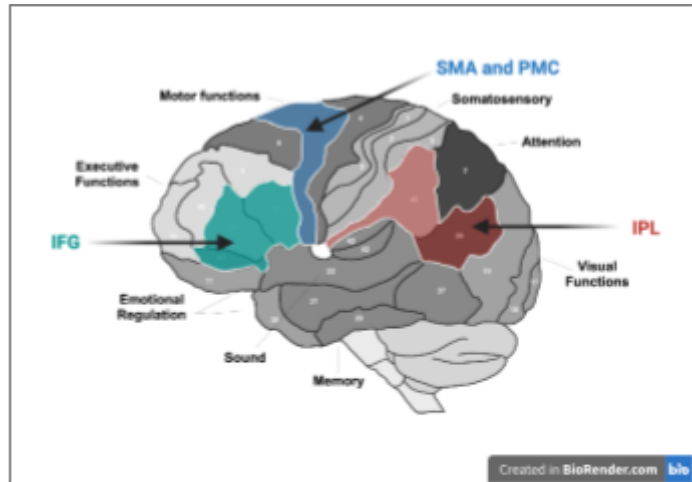
the premotor cortex is also activated when subjects attempt to recall a movement from memory, displaying the response of the PMC to both external and internal cues. In addition, when the premotor cortex of monkeys is damaged, the monkeys demonstrate decreased ability to select appropriate movements based on visual cues, even if they can still physically perform the movement. This suggests the premotor cortex is largely involved in selection of actions based on external and internal stimuli (Purves et al., 2001). It is evident that the premotor cortex would have a large role in dance, due to the need for dancers to plan out their movements based on taught choreography, their surroundings, and more.

This study also focuses on the supplementary motor area (SMA), which plays multiple roles in motor, sensory, language, and memory contexts. The SMA is divided into two distinct regions known as the SMA proper and the pre-SMA. For the sake of this study, the focus will be on the SMA proper, and further use of the term supplementary motor area will refer to the SMA proper. Similarly to the premotor cortex, the supplementary motor area is involved in the planning of movements. Studies have revealed that SMA activation occurs before movements are initiated, indicating its role in motor planning. In addition, SMA activation has also been shown to occur when individuals imagine movements, even if the physical movements are not actually carried out. Damage to the supplementary motor area results in impaired ability to carry out complex movements and to speak articulately, revealing the roles of the SMA in elaborate movement and language. The supplementary motor area also has spatial and temporal functions. Overall, the SMA is known to be functionally heterogeneous due to its various roles in the brain (ScienceDirect, 2012). The SMA's functions in movement planning, motor control, and timing, clearly correlate to its role in the observation and execution dance, an art form which requires all of these functions.

The third region is the inferior frontal gyrus (IFG), which has key roles in language, memory, and empathy, as well as action observation and execution. The left inferior frontal gyrus is crucial for language and speech, and lesions in the IFG can cause challenges in speech, as well as reading and writing. The right IFG is primarily involved in inhibitory control, and disorders such as attention-deficit hyperactivity disorder (ADHD) and obsessive-compulsive disorder (OCD) are associated with abnormal right inferior frontal gyrus structure or activity. The IFG has also been shown to have roles in social cognition and empathy, a key function of the mirror neuron system. The left IFG in particular has demonstrated significant activation during empathy, and damage to the inferior frontal gyrus has been associated with difficulty recognizing emotions. Fine motor control is also controlled from a cluster in the right IFG (ScienceDirect, n.d.). Altogether, the inferior frontal gyrus is involved in speech, inhibitory, empathy, and motor control, and it is clear to see that it would be highly activated during dance, due to dance's requirement of many of these functions.

Lastly, the final region of interest for this study is the inferior parietal lobule (IPL), which has crucial roles in social cognition, making connections, and body awareness. Neural activation of the inferior parietal lobule has been linked to various functions. The right IPL has important roles in visuospatial attention, and damage to this region can result in failure to correctly orient visual attention. The left IPL

has critical functions in language understanding, as well as semantic processing. Semantic processing can be defined as the interpretation of context and involves connecting words and phrases to deeper knowledge or concepts. For this reason, semantic processing is greatly intertwined with social cognition, indicating the IPL's role in interpersonal interaction. Additionally, the inferior parietal lobule is extremely involved in functional connectivity, and is connected with various other regions as part of larger neural networks (Numssen et al., 2021). Lastly, the IPL of monkeys has shown activation when the animals both observe and carry out actions, indicating its roles in action observation and execution (Fogassi, 2005). The inferior parietal lobule's roles in visual, spatial, social, and observational contexts clearly reveal its necessity in dance contexts, as dance, especially group dance, involves all the aforementioned functions.



**Figure 1.** Brodmann areas corresponding to key mirror neuron-related regions

Visual representation of the premotor cortex (PMC), supplementary motor area (SMA), inferior frontal gyrus (IFG), and inferior parietal lobule (IPL) shown by their respective Brodmann areas for anatomical reference. Figure created using BioRender.com, with brain schematic adapted from SimplyPsychology.org.

The use of Brodmann areas is a common methodology to organize the brain's cerebral cortex. Named after German neuroscientist Korbinian Brodmann, the 52 Brodmann areas remain the standard in modern neuroscience to map the brain under a shared system (Guy-Evans, 2021). **Figure 1** displays the four regions of interest for this study by their respective Brodmann areas.

Human mirror neuron research relies on indirect measures which capture overall neural dynamics in mirror neuron-related regions (such as the four regions of interest) as opposed to single-neuron firing. The neuroimaging techniques considered in this study are electroencephalography (EEG) and functional magnetic resonance imaging (fMRI).

Electroencephalography (EEG) studies measure electrical activity produced in the cortical areas in the brain when multiple neurons fire together. EEG signals oscillate at various frequencies, measured in Hertz (Hz). The most commonly used to study dance is the alpha frequency band, ranging from 8-13 Hz. As a specific example, mu rhythm is an alpha frequency oscillation recorded over the motor cortex. Mu rhythm actually decreases when an individual performs or observes an action, so higher mu suppression can be interpreted as an indirect marker of higher mirror neuron-related activity. However, it must be noted that EEG caps are placed on the scalp and not directly into the brain. As a result, mu and alpha oscillations are indirect measures of mirror neuron activity but still highly effective.

Functional magnetic resonance imaging (fMRI) measures blood oxygenation in the brain. Active neurons require more oxygen, and areas with active neurons have increased blood flow. fMRI detects this change in blood flow and emits signals called Blood-Oxygen-Level Dependent (BOLD) signals. While BOLD signals do not directly measure mirror neuron activity, higher BOLD signals in the premotor cortex, supplementary motor area, inferior parietal lobule, or the inferior frontal gyrus during dance could indicate higher mirror neuron-related activity. Therefore, similarly to mu and alpha oscillations, BOLD signals are indirect indicators of mirror neuron activity.

Due to the nature of these modalities, individuals are still able to move while their brain activity is being recorded. These technologies also easily facilitate the observation of dance. EEG and fMRI analysis allows for the individual to continue movement while collecting findings, enabling these machines to study dancers in a naturalistic setting. This research provides a narrative synthesis of studies to compare the activation of the mirror neuron system in individual observation learning as opposed to group synchrony in different styles of dance by synthesizing existing EEG and fMRI findings. As previously stated, since both EEG and fMRI measure indirect neural signals, not single-neuron firing, references to mirror neuron-related activity in this paper refer to increased activation in mirror neuron-associated regions, not direct mirror neuron firing.

For the sake of this paper, individual observational learning in dance can be defined as solitary imitation of an instructor, a dancer practicing by themselves, observing individual dance, or online learning. On the other hand, group synchrony in dance refers to learning, practicing, coordinating, observing, and performing dance with two or more people. Group dance involves a special synchronization with another individual that individual learning lacks. These two processes are closely connected but certainly have significant differences that will likely influence their effects on the brain.

Group synchrony in dance requires not only imitation but also the continuous prediction of others' movements and timing. Dancers must adjust their actions in real time to maintain alignment and synchronization with others, engaging neural mechanisms related to observation and social cognition. These demands suggest that group dance may place greater strain on the mirror neuron system than individual observational learning alone, consequently leading to more activation in MNS-related regions.

Therefore, while both individual observational learning and group synchrony in dance are expected to stimulate mirror neuron-related regions, group synchrony is hypothesized to be associated with greater activation, as measured by EEG and fMRI, due to the added demands of imitation, prediction, and coordination with others.

This study aims to address a gap in current scientific literature. Many existing studies investigate the neural mechanisms involved in dance, but rarely compare individual and group learning in dance. Dance is a unique combination of movement, music, and learning, and its effects on the brain should be further studied in multiple contexts. Due to dance's ability to stimulate multiple brain systems, the application of dance to therapeutic measures could assist in the prevention of neurodegenerative diseases. For example,

neural diseases that affect motor control or memory, such as Parkinson’s or Alzheimer’s disease, can potentially be prevented through dance-related therapies.

## METHODS

### A. Study Design

This paper uses a literature review to examine activity in mirror neuron-related regions during dance and its observation. The main database used was Google Scholar, which led to other databases such as PubMed, ScienceDirect, and Frontiers. Out of the 31 scientific articles initially investigated for use, ten papers were isolated as relevant to this study. The ten papers were selected based on their neuroimaging methodologies, direct engagement with mirror neuron-related regions, and application to dance or dance observation. The aforementioned papers are listed in **Table 1**.

**Table 1: Overview of Studies Included in the Results and Analysis**

Neuroimaging Methodology	Individual Dance Contexts	Group Dance Contexts
EEG	Brain correlates underlying creative thinking: EEG alpha activity in professional vs. novice dancers (Fink et al.)	EEG of the dancing brain: Decoding sensory, motor and social processes during dyadic dance (Bigand et al.)
	Cortical oscillations are modified by expertise in dance and music: Evidence from live dance audience (Poikonen et al.)	Contact Improvisation Dance Practice Predicts Greater Mu Rhythm Desynchronization during Action Observation (Goldman et al.)
fMRI	Trait representation of embodied cognition in dancers pivoting on the extended mirror neuron system: a resting-state fMRI study (Yang et al.)	Movement synchrony among dance performers predicts brain synchrony among dance spectators (Orgs et al.)
	The Dancing Brain: Structural and Functional Signatures of Expert Dance Training (Burzynska et al.)	Enhanced neural synchrony associated with long-term ballroom dance training (Wu et al.)

	<p>Building a motor simulation de novo: Observation of dance by dancers (Cross et al.)</p>	<p>Mutual gaze and movement synchrony boost observers' enjoyment and perception of togetherness when watching dance duets (Cross et al.)</p>
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**B. Search Strategy**

Search strings were based on a set of key words, adding or removing these terms to facilitate efficient searches. The search terms used were “mirror neurons,” “dance,” “individual learning,” “dance observation,” “group synchrony,” “partner dance,” “EEG,” and “fMRI.” Search terms were combined in strings of two to four at a time to facilitate efficient searches (e.g. “mirror neurons” AND “dance observation” AND “EEG”). Articles were first screened by title and abstract to determine their relevance to this paper, and then fully reviewed to confirm inclusion or exclusion.

**C. Inclusion Criteria**

Studies were included if they met the following criteria: (i) the study used EEG and/or fMRI to measure neural activation, (ii) the study measured full brain activation or activation in one or more of the focus areas: premotor cortex, supplementary motor area, inferior frontal gyrus, inferior parietal lobule, (iii) the study involved participants of any age engaged in any style of dance, or a similar audiovisual or movement-based activity, (iv) the study examined individual observation, partner/group activity, or both, and (v) the study was conducted between the years 2000 and 2026. The 10 studies listed in **Table 1** met all criteria. Studies were excluded if they: (i) did not use either EEG or fMRI, (ii) did not report on neural activity in one or more of the aforementioned focus areas, (iii) focused on motor or artistic activities highly unrelated to dance, or (iv) did not use methodological neuroscientific data to interpret findings. Additionally, only published, peer-reviewed, English studies were included, and the exclusion of non-English and preprint work could include selection bias. However, the steps mentioned above were strictly followed to reduce bias and maintain consistency as much as possible.

**D. Analytical Approach**

Studies were analyzed by identifying recurring patterns in the collected data. By comparing neural activation patterns in individual dancing versus group contexts, results were collected to effectively compare the two. Grouping findings thematically allowed for a clear analysis of the results to better compare MNS activation. Research papers were grouped under either individual observational learning or group synchrony and further separated based on whether they used EEG or fMRI techniques.

## **RESULTS & ANALYSIS**

### **A. Individual Observational Learning**

Across studies, individual dance observation and performance is often associated with increased activation in the mirror-neuron related areas. Overall, it can be interpreted that the mirror neuron-related activation was stimulated by the one-on-one imitation, movement, rhythm, and active recall involved in dance contexts.

EEG studies provide strong evidence for engagement of MNS-related processes during individual observational dance. Several studies have demonstrated significant mu and alpha band suppression when participants observed dance movements. One such study comparing professional and novice dancers examined alpha-band activity during tasks involving creative dance-related imagination. Although not directly studying mirror neurons, this study provides evidence that dance expertise influences neural dynamics associated with motor imagery and internal simulation, processes that overlap with MNS-involved mechanisms. The findings showed that professional dancers exhibited greater alpha power suppression than novices. This increased suppression may reflect more efficient neural processing during internally generated movement representations and creative demands (Fink et al., 2009).

In addition, studies examining dance observation found greater mu suppression in dancers than novices, when both groups were observing dance. A study by Poikonen et al. (2024) revealed that dancers observing a dance performance showed decreased spectral power when compared with non-dancers and musicians, suggesting possible greater engagement of sensorimotor-related processes in trained dancers when observing dance. The observed sensorimotor activity is commonly interpreted as reflecting action observation and internal motor simulation mechanisms that overlap with mirror neuron-related functions. This suggests that past individual dance experience is correlated to increased engagement of sensorimotor areas and MNS-associated activity even in the absence of physical movement. Overall, EEG studies reveal the stimulatory effects of dance and dance observation on action observation and motor networks.

fMRI research further supports the involvement of action observation networks associated with the mirror neuron system in individual observational dance learning. Studies report consistent activation in mirror neuron-related regions in dancers, even in resting states. An fMRI study comparing the resting states of dancers and non-dancers highlighted the increased communication of regions such as the inferior frontal gyrus and the premotor cortex in experienced dancers. The results revealed noteworthy differences in functional connectivity through BOLD signals, displaying the effect of dance experience on resting state neural activity. This provides indirect support of the engagement within extended mirror neuron-related networks, due to the role of the MNS involved in functional connectivity. (Yang et al., 2023).

In addition, during selected methods of measuring dance skill or simple dance observation, experienced dancers exhibited enhanced communication between motor and action observation networks. These differences were evident in networks involving all four regions of interest: the inferior parietal lobule, inferior frontal gyrus, premotor cortex, and supplementary motor area. This data suggests that long-term dance training is associated with enhanced integration of neural systems supporting motor planning and action understanding, functions commonly associated with mirror neurons. (Burzynska et al., 2017; Cross et al., 2006). This research reveals the effect of dance experience on the brain, and how, over time, experienced dancers develop stronger functional connectivity within networks associated with the mirror neuron system.

Importantly, fMRI studies have also shown that networks involving the four regions of interest activate more strongly when individuals observe movements they are familiar with, as opposed to unfamiliar movements. Experienced dancers exhibit greater and more widespread activation in these MNS-associated regions when watching videos of known choreography compared to new choreography, indicating that expertise strengthens the connection between observation and execution (Cross et al., 2006).

Overall, while MNS-associated activity varied based on expertise and familiarity, individual observational dance and dance observation consistently engaged mirror neuron-related regions and processes through internal motor simulation. Furthermore, dance expertise was linked to heightened activity of action observation networks during dance observation, demonstrating the connection between dance experience and neural mechanisms.

## **B. Group Synchrony**

Similarly to individual learning, studies examining group or synchronized dance suggest engagement of mirror neuron-related regions involved in coordination, motor control, and music. However, group dancing provides the additional element of synchronizing with another person.

EEG studies of group dance highlight the role of neural synchrony in MNS-related activation. When individuals dance in synchrony, EEG recordings show increased coherence in sensorimotor rhythms across participants, indicating shared neural timing.

One EEG study examined neural activity during dyadic dance, in which pairs of dancers coordinated their movements in real time. The findings showed modulation of sensorimotor rhythms, including mu and alpha band activity, alongside increased neural synchrony during coordinated movement with a partner. The results indicated that EEG signals were not significantly affected by self-generated movements, but were significantly affected by observation of and coordination with another individual. These neural patterns reflect the combined demands of action observation and interpersonal coordination that are characteristic of group dance. By requiring dancers to remain aware of a partner's movements, dyadic dance engages neural processes commonly associated with mirror neuron-related networks more extensively than individual movement (Bigand et al., 2025).

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Another EEG study examined whether long-term training in contact improvisation dance, a style of dance that relies on continuous interpersonal coordination, influences neural responses in the motor cortex during action observation. The results showed that individuals with greater contact improvisation experience demonstrated significantly stronger mu rhythm desynchronization while observing actions compared to those with less experience. Since mu power is a well-known marker of sensorimotor engagement during action observation, these findings suggest that sustained group and partner-based dance practice may enhance the responsiveness of neural mechanisms associated with action observation. This study provides EEG evidence that group dance training can amplify neural activation involved in action observation, even when individuals are later tested alone (Goldman et al., 2021).

fMRI studies examining synchronized or partner dance demonstrate increased activation associated with common mirror neuron-related functions, especially in regions with roles in social cognition. A preprint study by Orgs et al. (2024) comparing dancers and novices found that dancers showed consistent bilateral activations of the premotor cortex when watching group dance. In addition, the multiregional brain coordination in the novices was mainly due to the overwhelming amount of movement, as opposed to the dancers, who experienced interpersonal neural synchronization with other dancer observers heavily due to the relationships between performers. The results demonstrated neural synchrony between the experienced dancers as they watched dance, revealing that brain synchrony may reflect not only coordinated movements, but also on shared experience. These findings support the idea that dance expertise modulates how group synchrony is neurally processed by observers (Orgs et al., 2024). This pattern of shared activation indicates that group synchrony and common training backgrounds may indirectly shape how mirror neuron-related networks are engaged during dance observation.

Another fMRI study describes the enhanced neural synchrony experienced by dancers viewing dance videos as opposed to neutral videos. This coordinated neural activity is specifically associated with ballroom dance, as that is the type of dance the dancers were experienced in. As the trained dancers viewed videos of dance, they experienced similar increased functional connectivity. The participants' ballroom dance training was associated with increased functional connectivity in activity across key regions commonly associated with mirror neurons, such as the inferior parietal lobule and the inferior frontal gyrus, indicating the strong link between group dance experience and increased functional connectivity (Wu et al., 2023). The fact that the observers experienced neural similarities between one another in mirror neuron-related regions reveals the presence of neural group synchrony as well as connection due to shared expertise. This additional synchrony was not only linked to mirror neuron-related activity, but similar patterns of it between separate individuals.

An additional unique study investigated how mutual gaze and movement synchrony between dancers in a duet influence observers' perceptions while watching group dance. The findings showed that synchronized movement and shared gaze increased observers' feelings of enjoyment and social connectedness. The study demonstrates higher signal changes in regions such as the IPL and SMA (which are involved in the action observation network) when observing synchronous dance, suggesting that increased action and observation are linked to synchrony (Cross et al., 2024). Since these functions are

commonly associated with mirror neurons, the study demonstrates the correlation between interpersonal synchrony, enhanced activation of mirror neuron-related regions, and broader action-observation networks. Together, the results indicate a relationship between partner/group synchrony and heightened engagement of neural systems involved in action observation.

In conclusion, group dance appears to involve added neural demands, as both dancers and observers are required to synchronize with multiple individuals. In addition, experienced dancers exhibit elevated levels of interpersonal neural synchrony when observing synchronized group dance. These findings suggest that group dance may further amplify MNS-related activity by combining motor imitation with interpersonal interaction.

### **C. Comparative Analysis**

Across EEG and fMRI studies, results vary depending on expertise level, task complexity, and experimental design. Many studies rely on small sample sizes or artificial laboratory settings, limiting naturalistic validity. Furthermore, EEG and fMRI measure different aspects of neural activity, making direct quantitative comparisons difficult.

While both individual and group dance contexts are associated with mirror neuron-related activation, they possess certain crucial differences concerning their neural demands. Individual observational learning primarily relies on internal motor simulation, memory, and imitation, leading to strong MNS-related engagement during observation and recall. In contrast, group synchrony adds the requirement of real-time interpersonal coordination, requiring constant prediction and social connection.

The studies regarding individual dance consistently demonstrated that dance expertise is associated with higher MNS-related activation during dance observation, and even at rest. In addition, mental choreography was shown to further elicit stronger engagement of mirror neuron related-functions in dancers than in non-dancers. Previous dance experience can also be linked to increased MNS-related activity as individuals observed partner or group dance. It is also interesting to note how experienced dancers observing synchronized group dance often exhibit similar patterns of functional connectivity, suggesting the presence of interpersonal neural synchrony shaped by shared expertise.

Overall, the included studies provide evidence that both individual and group dance engage various neural networks involving functional connectivity among regions supporting mirror neuron-related functions. While direct comparisons between individual and group dance are limited due to the varying natures of the studies, the findings suggest that the added demands of interpersonal synchronization in group dance could contribute to greater engagement of mirror neuron-related processes through increased integration across motor, observational, and social networks.

Unresolved questions include how dance-induced activation in mirror neuron-related regions could be further explored or applied in a real world context. Few studies examine how these neural effects could be applied in therapeutic, educational, or rehabilitative settings, highlighting an important avenue for

potential future research.

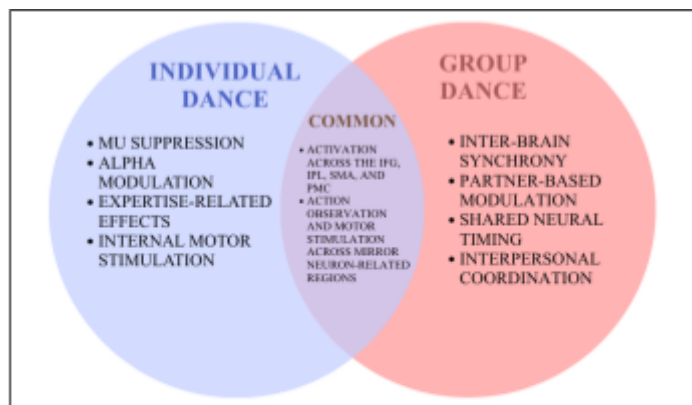
## DISCUSSION

### A. Summary of Key Findings

This review suggests that the mirror neuron system supports imitation, adaptation, and coordination in individual dance. Activation in key mirror neuron-related regions is also characteristic of functional connectivity, and neural synchrony is greatly associated with the mirror neuron system. The MNS could play an expanded role in group synchrony, due to the extra coordination required to dance with multiple dancers. While individual learning does strengthen observation and imitation, group dance involves these processes and combines them with social synchrony. In group dance, there exists the necessity to predict the movement of others, observe the actions of multiple individuals, and involve motor, social, and action observation networks of the brain. This recruitment of additional neural processes beyond individual learning may contribute to increased mirror neuron-related engagement. However, as none of the studies directly compared individual and group dance, more research is needed to concretely state that group dance causes increased mirror-neuron related activity. As of now, this conclusion remains tentative. **Figure 2** summarizes the overlapping and distinct neural processes observed in both individual and group dance, emphasizing how individual dance primarily involves experience-based neural benefits and group dance additionally involves interpersonal synchrony and shared neural timing. The figure reinforces the idea that both dance contexts are correlated with activation in mirror neuron-related regions.

### B. Theoretical Implications

These findings contribute to understanding mirror neurons as not only a mechanism for individual coordination but also for group harmony. MNS-related activation increases during both individual and group dance, supporting the role of mirror neurons in motor, learning, and coordination processes. Group dance bridges both dance and a social environment, and the link between motor to social cognition likely amplifies engagement of mirror neuron-related systems.



**Figure 2.** Venn Diagram Summarizing Key Findings

Concise summary of the principal findings of the review, with the left circle (individual dance) highlighting experiential effects and sensorimotor stimulation, the right circle (group dance) focusing on interpersonal synchrony and coordination, and the central overlap (common) emphasizing the shared activation across the SMA, IFG, IPL, and PMC.

While mirror neuron-related networks support neural synchrony, similar neural synchronies were observed in multiple people with similar dance backgrounds. This indicates that the MNS not only increases connectivity in our brain but also our connectivity to others, especially in those with shared backgrounds in neurally stimulating activities, such as dance.

In addition, as demonstrated by many of the included studies, dance expertise plays roles in strengthening observation, imitation, and the processing of synchrony. This indicates specific benefits among the many effects that dance has on the human brain.

### **C. Practical & Therapeutic Implications**

Potential applications include dance and movement-based therapy to address neural diseases that hinder movement, such as Parkinson's disease. This would include motor rehabilitation and movement learning. Based on the patterns observed in group dance studies, these therapies can be implemented in group settings. The greater MNS-related activation suggested in group dance indicates that the brain could be more stimulated in group settings, allowing for more effective therapy. Due to the potential neural benefits of group dance, group therapy could provide additional benefits.

It is important to note that the therapeutic implications discussed here are theoretical, and do not reflect pre-established outcomes. While dance and movement-based therapy has shown promising neural results in prior research (Wu et al., 2022), the specific role of mirror neuron-related activation has not been directly confirmed. The suggestions that group-based dance therapy could enhance neural stimulation are based on patterns observed in the reviewed studies, not on controlled, clinical trials. Further research is required to confirm the true neural advantages of group dance therapy over individual dance therapy in the context of mirror neuron-related stimulation.

### **D. Limitations & Future Directions**

A major limitation in this study is the scarcity of direct comparisons of individual and group dance. Results from separate experiments on individual and group dance were collected and presented together, but very few studies exist that consider both types of dance. Hence, the conclusion that group dance contributes to increased mirror-neuron related engagement is highly tentative. Although this study identified patterns to suggest the added effects of group dance, more concrete research is necessary to certainly determine this conclusion. Claims of group synchrony having greater effects on mirror neuron-related activity should be interpreted with caution, as they are inferred from the varying collection of studies used in this review.

Beyond the dearth of direct comparisons between individual and group dance, additional limitations of the studies included in this paper must be addressed. Many studies relied on relatively small sample sizes, with some as low as 10. This limited the generalizability and statistical weight of their findings. Second, while some studies were held in typical dance spaces, many were carried out in the laboratory, which could be a poor reflection of a real-world dance environment, limiting the ecological validity of these

papers. Additionally, many included studies compared expert and novice dancers. Dancers and non-dancers differ in several cognitive, motor, and experience-related factors that can not be completely controlled, making it difficult to isolate the contributions of dance training alone. Lastly, the different modalities, EEG and fMRI, both measure fundamentally different aspects of neural activity, causing direct comparison across these two neuroimaging technologies to be very complicated. This methodological constraint limited the direct comparison of fMRI and EEG results.

In addition, there is a copious amount of studies focused on observers of dance. Future research could greatly expand studying individuals while they are performing dance. Due to the nature of methodologies such as EEG which allow for free movement, the opportunity to examine dancers' brains as they dance is in reach, and should be taken. Lastly, the types of dance included in these studies were very limited. There was a particular scarcity of studies on Asian and African traditional dances. Dances from different cultures involve different aspects of language, storytelling, music, and more, and the effects of different dance styles on the brain should be further explored. These constraints should be taken into account when interpreting this review's claims regarding mirror neuron-related engagement in dance.

Future research should directly compare individual versus group dance and their effects on the mirror neuron system using controlled paradigms and one method of measurement. Because EEG measures temporal dynamics while fMRI measures spatial activation, this methodological mismatch limited direct quantitative comparison. Expanding on this study could include examining how social context, age, dance style, and other aspects besides individual versus group learning influence mirror neuron activation. Since the mirror neuron system is key in important functions like imitation, coordination, and learning, ways to better stimulate and activate it should be studied more in depth. In addition, future studies could explore methodologies to directly measure mirror neuron system activation in dance, as opposed to indirect measures such as those discussed in this study.

The potential applications of both dance and the mirror neuron system make future research in these areas essential for developing innovative therapeutic strategies. Dance uniquely combines motor execution, action observation, and social coordination, allowing for heightened engagement of various neural networks, including those related to mirror neurons. The overarching effects of dance on the brain cannot be ignored, as they highlight the powerful impact of artistic movement on neural synchronization and human connection.

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