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The social and neural bases of creative movement: workshop overview

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Abstract
This editorial provides a background and overview of the interdisciplinary workshop on "The Social and Neural Bases of Creative Movement," bringing together dancers, choreographers, musicians, artists, kinesiologists and neuroscientists to share perspectives and develop a common language to define and explore the relationship between dance and the brain.

Introduction

An international interdisciplinary workshop, focused on the theme of "*Social and Neural Bases of Creative Movement,*" was convened April 7–10, 2022, amidst the beautiful, natural settings of Wolf Trap, the National Park for the Performing Arts in rural Virginia. The workshop brought together an exceptionally wide range of artists and scientists to exchange ideas, to share differing perspectives on the creative process, and encourage reaching out beyond the confines of participants' expertise to identify common interests and common ground. Most of all, however, the goal of the workshop was to explore new ideas and ways of thinking to catalyze novel research directions, collaborations and creative approaches that will deepen our understanding of the neuroscience of dance. We are very grateful to the NSF, NIH and NEA for providing funds to make this exciting and innovative Workshop possible, and include the insightful perspectives from contributing Program Directors below in a separate section.

Why creative movement?

Dance and other forms of creative movements can be aesthetic or symbolic, but above all, are an artistic expression of the performer's thoughts and feelings. It can be directed inwards to invigorate, relieve, or delight the performer. Or, dance can communicate feelings to a viewer, to tell a story, to perform a ceremonial ritual, to create an impression. From an artistic perspective, on the one hand, dance is like music and the visual arts, a creative activity that has engaged and shaped all human cultures over many millennia. Dance is ancient – humans have been moving and feeling much longer than they have been talking and writing. Dance is incredibly diverse, ranging from ballet to break dancing to shamanic enactments of hunting, and is often accompanied by other forms of artistic expression such as music, masks, costumes, scenery that enrich its meaning and enhance its artistic power. Dance has evolved in form, purpose, and technique, reflecting the evolution of the human mind and societies. Communal participatory dance can

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be a joyous gathering that promotes social bonding, and movement like Tai Chi and Capoeira can also be stylized forms of exercise and martial arts. But in its essence dance is a form of communication and expressive movement that has evolutionary origins that humans share with other social animals [1] with rhythmic motor actions [2] that include intricate courtship dances of bowerbirds, headbobbing parrots, moonwalking red-capped manakins, honeybees' waggle dance and even dances of peacock spiders, weedy sea dragons and Spanish dancing sea slugs. Recent studies of songbird pair duets recorded in the wild have revealed the neural basis of dueting behavior [3]. Therefore, from a scientific perspective, human dance offers an exquisite paradigm with ancient antecedents that combines sensory perceptions with an intricate sequence of motor actions in complex ways that transcend the habitual repetitive patterns of everyday life, that can be analyzed with computational kinematics [4], that often requires focused training to perform and hence offers a superb model for motor learning, sequence encoding and memory, brain plasticity [5, 6] and an opportunity to study the interactive dynamics between dancers, and the art of expressive movement that communicates to an audience.

Why neuroscience?

We are just beginning to understand the intimate relationship between creative movement and the human mind. For neuroscientists, dance offers a remarkable opportunity to explore the neural and cognitive basis of why humans spontaneously dance to music [7], how complex sensory-motor interactions can be created, developed and fine-tuned in solo and partnered dance [8], how choreography and complex movement sequences are learned and encoded in the brain, and how dance is perceived by viewers. Neurologists study the neural basis of movement disorders and how they can be treated. For kinesiologists and other health professionals, dance serves as a model activity, and form of exercise, that induces powerful sensations both internally and in others, and in so doing can enhance the emotional well-being and physical quality of life in chronically-affected individuals and can be invaluable in rehabilitation and therapy [9]. The emerging fields of choreorobotics [10] and neurorobotics [11] are at an exciting interface between dance, choreography, neuroscience, neuroengineering and robotics [12]. A major goal of the Workshop was to deepen these scientific insights and encourage the active engagement between dancers, choreographers, kinesiologists, roboticists, neurologists and neuroscientists to foster stronger communication, collaboration and lasting mutual influences, and collaborative between these communities.

Previous dance and brain meetings

There is growing, worldwide interest in the interdisciplinary field of dance and neuroscience. Our Workshop (2022) was unique in its broad scope and wide range of topics and participants [13]. A partial list of other related meetings and events include the "Dance and Academia" seminar series and workshops (2008–2019), led by Miranda Laurence (Oxford University), which aimed to bring dance practitioners (including choreographers) in touch with academics interested in dance, both scientifically and artistically, as well as lay people who love dance or are interested more generally in movement [14]. Other events of a similar flavor were workshops on "The Science of Joint Improvisation" held in Paris (2015, 2018) and organized by the Joint Improvisation Lab at the National Center for Scientific Research (CNRS). These were international workshops dedicated to the scientific investigation of joint improvisation and social interaction in dance, theatre and music with contributions from multiple fields including neurosciences, biology, linguistics, sociology, anthropology, philosophy, performance studies among others. Another Paris workshop [15] "La Dynamique Interactionnelle du Geste" held in 2016 brought together researchers, philosophers and practitioners who are studying gestural communication in both linguistic and non-linguistics domains to present and discuss their respective projects and to exchange questions, tools and perspectives concerning the framing of research questions, novel methodologies and potential synergies. There have been several smaller workshops that combined Science and Dance that took place in Germany [16] and at the University of Manchester in the United Kingdom. Georgia Tech hosted a series of lecture-performances on dance and the brain [17] (dance, artificial intelligence and neuroethics (2022) and dance and Parkinson's disease [18] (2024)). There were a series of workshops in Canada focused on the creative process [19] that emphasized the mathematical and computational modelling of artistic expression that could be captured by these abstractions as part of the annual ACM Creativity and Cognition Conferences, that explore the interaction of creativity and cognition in all realms.

Principal sponsors and organizers

The idea for the Wolf Trap Workshop on "*Social and Neural Bases of Creative Movement*" arose in discussion and crystallized with encouragement from educational and scientific leaders at the National Science Foundation. Soon thereafter, additional support came from the National Endowment for the Arts and the National Institutes of Health that helped to broaden the vision and scale of the workshop to go beyond the science, and into the health and educational aspects of creative movement. Finally, many other organizations were instrumental in

supporting participating artists and performers, as well as facilitating the use of the spectacular venue at Wolf Trap. These included the University of Maryland (College Park), the University of Houston, and the Wolf Trap Foundation. The initial organization and planning for the Workshop was carried out by Shihab Shamma (University of Maryland College Park), Jonathan Fritz (New York University), Jose Contreras-Vidal (University of Houston) and Vered Aviv (Jerusalem Academy of Music and Dance). We are grateful to many other individuals who played key roles in advising us as to the structure of the workshop, topics to cover, organization of the sessions, and the best representative scientists, artists, and practitioners to invite.

Perspective from the funding agencies on the genesis and goals of the workshop

Soo-Siang Lim (NSF), Betty Tuller (NSF), Emmeline Edwards (NIH) and Sunil Iyengar (NEA)

We are delighted that the workshop "Social and Neural Bases of Creative Movement" has led to the publication of this special issue. Creative movement is embedded in societies across cultures and across the ages. However, despite its ubiquity in human activity, our knowledge of this commonplace but complex phenomenon is quite sparse and scattered across research disciplines and various professional sectors in science, health and the arts.

A motivating scientific interest for this workshop is that movement recruits a broad array of sensory-motor circuits in the brain required for synchronization, improvisation, and coordination, not only within an individual but across many people and with the environment. Creative movement offers a rich experimental paradigm within which a well-controlled set of actions can be examined to understand how the brain's underlying substrates of sensory-motor coordination not only learn the actions but transform them into artistic expressive movement. Indeed, creative movement could be conceived as a form of extreme skill learning, often requiring focused training, coupled with deep emotional and social engagement and mental imagery to allow creativity and innovation to emerge.

Creative movement often takes place in conjunction with music, presenting a possible bridge between research on auditory perception of music and rhythm and research on movement. The convergence of these areas, often pursued separately, offers opportunities to examine the dynamics of interacting brain areas to coordinate rhythmic sound with movement, how the body creates and recognizes temporal patterns, and how people and groups makes sense of time and coordinated timing.

These topics and extensions of their broader scientific and educational impacts are aligned with the research mission of several core programs within the US National Science Foundation (NSF), including the following co-funding programs that contributed to the Workshop: the Science of Learning and Augmented Intelligence (SL) Program, and the Perception, Action and Cognition (PAC) Program (both in the Social, Behavioral and Economic Sciences (SBE) Directorate), and the Mind, Machine and Motor Nexus (M3X) Program in the Engineering Directorate.

The ability to purposefully control and coordinate our bodies with sound cadence or tempo likely confers additional behavioral, cognitive and emotional benefits and has exciting applications. For example, clinical observations show that patients with Parkinson's Disease walk dramatically better when they can hear a metronome, sounds or music with a or strong rhythmic beat [20, 21]. Understanding how and why this happens could lead to better and more targeted therapies for people with neurologically based disorders that impact movement or motor learning.

The intersections of Arts and Health is a priority with the National Center of Complementary and Integrative Health (NCCIH), a component of the National Institutes of Health which also co-sponsored the Workshop. NCCIH's research programs are focused on increasing understanding of how the arts affect health with an emphasis on the basic neuroscience of various art forms and their potential clinical applications. Workshop presentations highlighted how active and passive engagement in creative movements (various forms of dance, dance improvisation, Tai Chi, Japanese Butoh, etc.) involve multimodal sensory-motor integration, models of learning and memory representation, mental imagery, means of communication, self-expression, and social bonding. NCCIH is engaging a cadre of interdisciplinary researchers to develop large-scale basic and clinical research programs aimed at understanding the psychological and physiological effects of creative movements on health and well-being.

In addition to awarding grants that support dance and dance education, the National Endowment for the Arts (NEA) which also supported the workshop through a Research Lab award to Rice University, funds research into the value and impact of dance—and, indeed, of all art forms—as revealed through physical, physiological, and psychological health outcomes. Recently, the NEA has funded two studies that examine dance among people with distinct neurological conditions. One is a program evaluation of a tango dance intervention in adults with Parkinson's disease, and the other is a study of the benefits of a community dance/movement program for people with multiple sclerosis. In addition, the agency supports the placement of dance therapists, music therapists, and art therapists in U.S. clinical care sites, to

address neurobiological and psychological traumas experienced by military patients and veterans.

The workshop's broader goal to foster collaborations between scientists and artists is central to its efforts to study creative movement in its many dimensions and contexts, in order to more fully understand its therapeutic and non-therapeutic benefits to human well-being and quality of life. The idea for the workshop originated with NSF as part of its participation in the Interagency Task Force for the Arts and Human Development (2011–2023), which had convened to promote research and evidence-sharing about the arts across government. It is fitting that such a transdisciplinary research topic as the neural and social bases of creative movement emerged from a forum designed to break siloes across federal agencies and departments, in pursuit of rigorous research that can make advances in human well-being and health.

Workshop organization

The meeting included six sessions of scientific topics, each with a mix of invited speakers/performers centered around a particular topic viewed from many contrasting viewpoints [14] and a final performance session to which the public was invited. The audience at the Workshop included a broad range of students and postdocs from many disciplines and faculty and professionals of diverse backgrounds. All sessions were video recorded and streamed live on the venue's website. The ideas and insights arrived at through workshop discussions and debates were the main tangible outcome of the meeting. The Workshop also showcased the latest technologies of mobile brain-body imaging which were discussed and demonstrated in performances during the sessions. The success of the Workshop also kindled interest and spurred additional support from the sponsoring agencies in the form of calls for funding for new research paths and collaborative projects in the Neuroscience and Dance themes.

Workshop topic sessions

There were several concurrent themes that ran throughout all sessions in the workshop They included: biological evolution of rhythmic movement and the social evolution of dance as one of the ancient arts and its relation to music; learning and memory of complex motor sequences in dance; transformation of movement and performance to artistic expression; action and performance to perception; creative embodiment to social empathy; group dynamics in dance; dance and health: therapeutic and the life-enhancing value of dance.

The seven sessions of the workshop were:

Session 1 History, Sociology, Evolutionary Biology of Dance.

Session 2 Cognitive Neuroscience of Dance.

Session 3 AI, Robotics, Technology and Dance.

Session 4 Embodied Cognition and Learning of Dance.

Session 5 Dance for Health.

Session 6 The Shared Experience of Dance.

Session 7 Performances at The Barns of Wolf Trap.

A summary of the different sessions is provided in a supplementary file to this article (Supplementary Material 1) that describes the contributions of Workshop participants, as well as additional links to highlight their interests. More insights, information and discussion are available in the articles contributed to this BMC Neuroscience special issue representing many of the talks and topics that were covered in the workshop.

Summary of articles in special issue

The article by Fitch et al. [22] seeks to formulate a new definition of dance from the perspective of motor learning and predictive coding and emphasizes the importance of conscious awareness in movement that they argue is the essence of dance. Hackney et al. [23] provide an overview of the cognitive neuroscience of dance – and explore the importance of creative movement as a model for motor learning and memory, multimodal sensorimotor integration, and mental imagery. Theofanopoulou et al. [24] provide a framework to study brain dynamics during dance in ecological settings using mobile brain-body imaging technology. Lopez-Ortiz et al. [25] offer fascinating insight into the therapeutic power of creative movement in dancers with cerebral palsy, and the effects of ballet training on body tone and the stretch reflex. The article by Theofanopoulou et al. [24] demonstrates the use of mobile brain-body imaging technology to study the neural basis of dance during rehearsals and performance. The article by Laroche et al. [26] proposes that in order to foster creativity and creative movement, it is necessary to go beyond the usual patterns of behavior by disrupting habitual patterns of movement. They argue that creativity arises in the course of a "De-Sync" process, that disrupts habitual synchronization, and can be facilitated by collective improvisation. The final article by Patel et al. [27] advances the thesis that beat-based dancing to music has evolutionary foundations in vocal learning in different vocal species. Because Patel's work has aroused great interest in ethologists, behavior scientists, linguists and neuroscientists, as well as dancers, we invited commentaries on Patel's article. The ensuing discussion in these five commentaries [28–30, 31, 32] and Patel's response

captures the vivid excitement of the interactions and perspectives at the Workshop.

Conclusion

We are deeply grateful and wish to thank the speakers, dancers, choreographers, scientists and all the participants and funding agencies for creating an incredible and exciting four-day journey of exploration into the nature of dance and creative movement, and its basis and representation in the brain. The Workshop brought together multiple communities from the arts and sciences, and sparked dialogue and new collaborations across traditional boundaries of expertise. We look forward to future developments in this field that promises to unify our understanding of dance and neuroscience, and the art of embodied, expressive and creative movement.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12868-024-00893-w.

Supplementary Material 1

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Author contributions
Shamma is the PI on the grant that funded the workshop from NSF and other sources indicated in the Introduction. He helped write the manuscript, and led the organization of the workshop and all its logistics Contreras-Vidal participated in the organization of the workshop and the writing of the manuscript. Fritz participated in the organization of the workshop, writing of the manuscript and the funding proposal. Lim, Edwards, Tuller, Iyengar are the Program officers from the funding agencies that helped make the workshop possible.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Disclaimer
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Competing interests
The authors declare no competing interests.

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