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Corresponding Author	Family Name	**Cross**
	Particle	
	Given Name	**Emily S.**
	Suffix	
	Division/Department	Department of Psychology
	Organization/University	Max Planck Institute for Human Cognitive & Brain Sciences
	Street	Stephanstr. 1a
	City	Leipzig
	Postcode	04103
	Country	Germany
	Phone	+49 341 9940 2671
	Email	cross@cbs.mpg.de
Author	Family Name	**Ramsey**
	Particle	
	Given Name	**Richard**
	Suffix	
	Division/Department	School of Psychology
	Organization/University	University of Nottingham
	Street	University Park
	City	Nottingham
	Postcode	NG7 2RD
	Country	United Kingdom
	Email	richard.ramsey@nottingham.ac.uk

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Neurophysiological Correlates of Learning to Dance

Emily S. Cross[1], Richard Ramsey[2]
[1]Department of Psychology, Max Planck Institute for Human Cognitive & Brain Sciences, Leipzig, Germany
[2]School of Psychology, University of Nottingham, Nottingham, United Kingdom

Synonyms

Action neuroimaging; Complex action learning; Dance learning

Definition

Humans possess an unparalleled ability to perform a seemingly endless variety of skilled actions. In dancers, this ability is even more pronounced, as their livelihood depends on rapid and precise reproduction of complex movements. Recent advances in neuroscience have enabled scientists to get a better look at how simple actions are coordinated in the brain. However, to better understand how more sophisticated, full-body movements are learned and reproduced, researchers are now turning to populations of expert and novice dancers to help illuminate how the brain learns to coordinate the body to perform complex and precise movements.

Theoretical Background

It has long been proposed that observing, imagining, or in any way representing an action engages similar neural processes as those used in execution of that same action (James 1890). A dominant theory to emerge from this early work by William James is the idea of common coding between perception and action. The basic idea behind common coding is that one understands other people's actions by using one's own motor system, and such a synergy between perception and action also aids in new action learning. More recently, technological advances in the brain sciences have resulted in compelling neurophysiological evidence that supports this assertion. In the mid-1990s, Giacomo Rizzolatti led a team of scientists who were the first to report evidence of a neural system that matches action with perception in the brains of nonhuman primates. These scientists discovered the special properties of a neuronal population almost by accident, when they were recording from single neurons within the ventral premotor cortex (area F5) of the monkey brain. The researchers observed, much to their surprise, that the same neurons that fired when monkeys performed a specific action (e.g., grasping a raisin) also fired when the monkey watched another monkey or a researcher execute the same action (Rizzolatti et al. 1996). Subsequent research revealed that these particular neurons, as well as a distinct population in the inferior parietal lobe, do indeed respond preferentially to actions that are either observed or performed, which led researchers to name them mirror neurons.

Since the discovery of mirror neurons in monkeys, scientists have found a similar neural system that links action perception with production in the human brain. Using neuroimaging techniques, such as functional magnetic resonance imaging (fMRI), a growing number of studies with human participants have demonstrated that premotor and parietal cortices also show similar responses to action perception and production (Grèzes and Decety 2001). As illuated in Fig. 1, the brain regions that compose the human mirror neuron system (MNS) include analogous brain sites as those first discovered in the monkey brain, the ventral premotor cortex (PMv) and the inferior parietal lobule (IPL), as well as several other regions, including the supplementary motor area (SMA), and superior temporal sulcus (STS). Thus, the human MNS appears to be a complex and broadly distributed cortical network that matches observation of actions with execution of those same actions.

The implications of a neural link between perception and action are broad reaching, extending well beyond simple grasping behaviors, and are consequently being explored by researchers from a diverse range of disciplines beyond neuroscience, including philosophy, sports science, cognitive psychology, occupational therapy, and, recently, the field of dance. By turning to populations of expert and novice dancers, neuroscientists can begin to address how brains and bodies transition from being able

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to perform such skilled and coordinated behaviors as walking up the stairs or tying one's shoelaces to even more skilled and coordinated behaviors, such as performing five consecutive *pirouettes* or dancing flamenco.

Important Scientific Research and Open Questions

Cognitive neuroscientists have increasingly been turning to dance to help address questions of complex action learning for several reasons. First, dance requires a great degree of coordination not only between the different limbs of one's own body, but also between one's own movements and the movements of other people. Dancers' ability to translate scant visual or verbal information into sophisticated movements holds great potential value to scientists. Not only can scientists learn about the coordination and expression of complex action by quantifying dancers' behavioral performance, but careful measurement of how such skilled actions are represented at the neural level can further illuminate how the human body is capable of learning and performing complex movements with different kinds of information (visual, verbal, symbolic, etc.).

In the past 5 years, a line of research performed with populations of both expert and novice dancers contributes an ecologically valid approach to investigating the brain bases of whole-body action learning (Calvo-Merino et al. 2005; Brown et al. 2006; Cross 2010). The first such study investigated the specificity of the mirror neuron system for observing one's own movement repertoire compared to an unfamiliar or untrained repertory (Calvo-Merino et al. 2005). In this experiment, ballet dancers, capoeira dancers, and non-dancer participants passively viewed ballet and capoeira dance clips while undergoing fMRI scanning. The authors reported significantly greater activity within the MNS when dancers observe the movement style with which they have the most expertise, whereas a similar pattern was not observed when non-dancers observed either dance style. From this, they conclude that the MNS integrates one's own movement capabilities with the observed actions of others, thus facilitating action understanding. In another highly innovative study, Brown and colleagues used positron emission tomography (PET) to investigate the neural substrates associated with core elements of tango dancing (entrainment, meter, and step patterns) by having participants physically perform the foot patterns on an inclined surface while lying in the scanner (Brown et al. 2006). Brown and colleagues report activation within a broad network of mirror system regions when executing complex foot sequences, and involvement of striatal and cerebellar components when more complex rhythmic sequences were performed. This study demonstrates that dance performance not only recruits MNS regions, but as temporal elements (such as the dance's rhythm) become more complex, subcortical brain regions are also required to support performance. The general pattern of activation in tango dancers' brains reported by Brown and colleagues is consistent with activation patterns reported during ballet, capoeira, and modern dance observation (Calvo-Merino et al. 2005; Cross 2010). In a series of three fMRI studies, Cross and colleagues observed that both expert and novice dancers showed stronger and more finely tuned neural responses within the mirror neuron system when watching movements they had previously physically experienced, and were highly skilled at performing (Cross 2010). These data suggest that the MNS adapts following physical and observational practice to become more finely tuned and thus capable of the type of physical expertise frequently demonstrated by dancers.

The results from such dance studies demonstrate an approach with increased ecological validity to study how we learn to coordinate our entire bodies to perform complex movements. It is certainly remarkable that the MNS, originally discovered in the brains of nonhuman primates, also exists in the human brain, and is recruited when learning highly sophisticated dance movement patterns. The challenge for future research in this field is to map out in finer detail the capabilities and limitations of the MNS during complex action learning. Continued use of dance paradigms will help to address such questions in two ways. First, in real dance scenarios, ranging from classical ballet to square dancing to social dancing in nightclubs, an individual must coordinate his or her movements with multiple other individuals. How the MNS represents and integrates perceptual information from multiple other bodies remains unexplored, and dance contexts should provide rich opportunities to investigate this fundamental question of action coordination in social contexts. Secondly, past studies on the neural underpinnings of dance have focused mostly on the visual components of dance observation, while dancing outside of laboratory contexts usually involves fine coordination of visual, motor, and auditory cues. For example, a key feature of learning a new dance work is being able to integrate one's (and other people's) bodily movements in close synchrony with music. Future work on the neural substrates of complex action learning can use dance paradigms to investigate how the brain and body learn to integrate information across several sensory modalities.

Cross-References

► Brain/Mind Learning
► Dancing: A Nonverbal Language for Imagining and Learning
► Expertise
► Neuropsychology of Learning

References

Brown, S., Martinez, M. J., & Parsons, L. M. (2006). The neural basis of human dance. *Cerebral Cortex, 16*(8), 1157–1167.

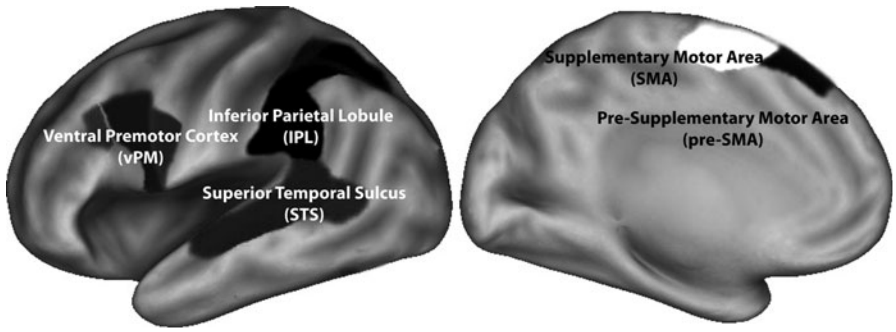
Calvo-Merino, B., Glaser, D. E., Grèzes, J., Passingham, R. E., & Haggard, P. (2005). Action observation and acquired motor skills: An FMRI study with expert dancers. *Cerebral Cortex, 15*(8), 1243–1249.

Cross, E. S. (2010). Building a dance in the human brain: Insights from expert and novice dancers. In B. Bläsing (Ed.), *The neurocognition of dance* (pp. 177–202). London: Psychology Press.

Grèzes, J., & Decety, J. (2001). Functional anatomy of execution, mental simulation, observation, and verb generation of actions: A meta-analysis. *Human Brain Mapping, 12*(1), 1–19.

James, W. (1890). *Principles of psychology.* New York: Holt.

Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Brain Research. Cognitive Brain Research, 3*(2), 131–141.



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Neurophysiological Correlates of Learning to Dance. Fig. 1

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