What Can Dance Teach Us about Learning?

By Scott T. Grafton, M.D.

About Scott T. Grafton, M.D.

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We might begin to learn a dance step when someone describes it to us, but we learn it better when we physically perform the steps as we observe and imitate an instructor doing them. Scott Grafton's research sheds light on the brain's action observation network, which fires up both when we perform an action and when we watch someone else perform it. Dr. Grafton contends that his and others' findings highlight the importance of including physical learning in the classroom, to stimulate creativity, increase motivation and bolster social intelligence.

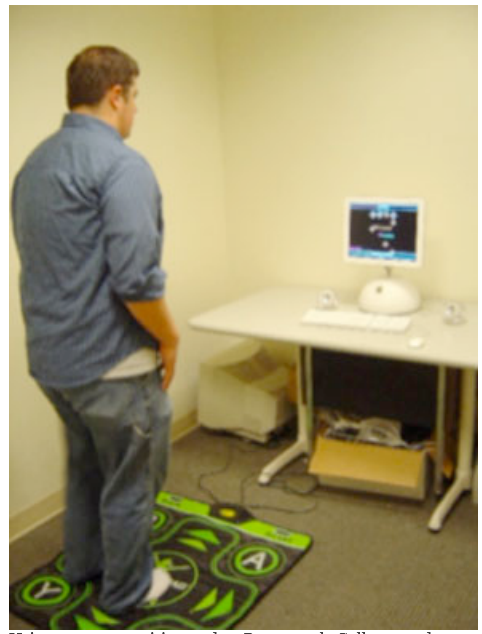
We use many mental and physical strategies, some more effectively than others, to learn new skills. Consider the challenge of learning a new dance step—whether something silly, such as the Hokey Pokey, or elaborate, such as a series of flamenco steps or a hip-hop "pop." Verbal descriptions of how, where and when to move our bodies can work pretty well if the dance isn't too complicated. As movements become more complex, however, our capacity to follow verbal instruction decreases. Words are too slow, general and serial to encapsulate all the details of a precise move.

One alternative to verbal instruction is to follow spatial guides—for example, by stepping on patterns traced on the floor. This old-fashioned method of dance instruction forms the basis of extremely popular computer dancing games such as *Dance Dance Revolution* and music games including *Guitar Hero* and *Rock Band*. To gain points, players must hit sequences of spatial targets at the correct times (with a song acting as a metronome) and with the correct body parts (feet, fingers or hands).

Observational Learning

Another way to learn is to observe and imitate a physical model. For example, thousands of online instructional videos use physical models to show us how to dance or how to play musical instruments. Through trial and error, learners refine their skills. Research shows that teaching via a physical model improves learning more than verbal descriptions or spatial guides. We also know that learners acquire a motor skill more rapidly and precisely if the model is a real person placed alongside the learner.[1] A real dance instructor, for instance, can adapt a lesson to individual strengths and weaknesses.

While words can help us start to learn a dance, ultimately we need to form nonverbal knowledge—what coaches incorrectly refer to as "muscle memory"—in order to dance anything complicated. Ample evidence shows that brain networks, not muscles, store memories of movements



Using a step-sensitive pad, a Dartmouth College student learns a complicated sequence of dance steps to a techno beat. In a later stage of this research, brain imaging detects activity in networks that are active both when we observe an action and perform it ourselves. (Courtesy of Scott T. Grafton.)

Could Action Observation Help Patients with Brain Injuries?

Imaging studies of the action observation network (AON) have helped scientists identify a powerful learning system in the brain that links perceived actions and self-generated behavior. These findings are generating excitement in the field of rehabilitation medicine because they suggest new approaches to help train people trying to regain motor function after brain injury from stroke or trauma. Observing others' actions, the theory goes, might activate still-healthy brain circuits—including the AON—and accelerate recovery. There are two potential limitations, however.

First, it would be naive to assume that all observations of actions in the physical world can directly transfer to performing a similar action without some trial-and-error learning. While observational learning supported by the AON probably provides a rough template for movement, real physical practice ultimately is unlikely to have a substitute. Therefore, a patient must have enough undamaged motor pathways from the brain to the spinal cord in order to generate some level of action to relearn given movements.

Second, the AON almost certainly depends on a large library of motor programs that we acquire throughout brain and body development, and these programs might be irreplaceable. We generally underestimate how much

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such as dance steps. These memories, which are called motor memories because they are specific to movement, are fundamentally different from memories of verbal descriptions of these same actions.

My research team, which is interested in how people create motor memories, studies the interplay between the brain networks we use to understand others' actions and the networks we use to generate movements. Observational learning is the *process* of modeling others' actions by observing their movements. This process has implications as far beyond the realm of dance as classroom education. We believe that neuroscientists' insights about observational learning are highly relevant to the growing field of neuroeducation and should influence decisions about what is taught in K–12 classrooms.

There are two questions critical to understanding observational learning: Does the brain use similar circuits both to recognize and to perform an action? And, if so, does this overlap constitute the neural basis for observational learning? Dance is a solid experimental medium for testing these questions, and our tests have yielded evidence that the brain has a shared network for observing and doing. This network allows us to simulate action and is thus a powerful learning engine.

A Familiar Dance Lights Up the Brain

Watching a video of Michael Jackson dancing fires up a widespread network in the cortex across the brain's hemispheres.[2] We have named this circuitry the *action observation network* (AON). To observe it we use magnetic resonance imaging (MRI), which creates images that reflect changes in brain blood flow and indicate which areas are active during a task. Strikingly, the AON includes many brain areas that are also active during actual movement. This fact contradicts classic descriptions that divide the brain into sensory and motor areas. The AON is a storehouse of physical knowledge—of the self and of other objects—that can be used both to understand and to plan action.

Discovery of the AON has revitalized interest in motor simulation theory, which holds that we use our own motor memories to figure out what other people are doing. When we watch a video of a dancer, motor areas of the brain might activate automatically and unconsciously—even though our bodies are not actually moving—to find familiar patterns that we can use to interpret what we are watching. In other words, some sort of resonance takes place between the circuits for observing and for doing. If this is true, the AON should be more active when we observe actions that are physically familiar than it is when we observe unfamiliar actions.

This theory is hard to test with everyday actions; it is difficult to find someone who is unfamiliar with picking up a coffee mug or walking across a room. In contrast, people differ significantly in their levels of dance experience and competence. For example, while many of us are familiar with the moonwalk, few of us can actually create this movement. Thus, we might expect to see more brain activity in someone watching a familiar dance than in someone watching the moonwalk.

In an innovative paper published in 2005, Beatriz Calvo-Merino and colleagues at University College London used functional MRI (fMRI) to compare brain activity in two groups of trained dancers—one skilled in ballet and the other in capoeira, an Afro-Brazilian dance based on martial arts movements. Both groups were exceptionally skilled at dance, but each knew a set of profoundly different dance movements. The study found greater activity in the AON when dancers watched videos of familiar dances than when they watched videos of unfamiliar dances. This result is consistent with the simulation hypothesis.[3]

Each troupe's dances were both visually and physically unfamiliar to those of the other troupe. This was a research-design weakness because

training occurs as a child develops into an adult. Consider a 14-month-old toddler learning to walk. He takes about 2,000 steps (almost half a mile) and 15 falls a day in a whirlwind of fearless trial-and-error exploration.[13] A few weeks of observational learning in an adult is unlikely to replicate the effects of many years of training.

Integrating these ideas, it is reasonable to propose that patients with brain injuries will make the greatest recovery when the training environment employs their existing movements and requires problem-solving that uses observational learning over a long period of time.

it raised the possibility that the AON became active due to visual familiarity rather than physical experience. Calvo-Merino's team addressed this question in a clever follow-up study in 2006. Male and female ballet dancers observed videos of ballet movements that only men or only women perform. The dancers were visually familiar with all movements but physically familiar only with those in which they were trained. Again, AON activity was greater when dancers observed movements with which they were physically familiar.[4]

Calvo-Merino's results suggest that dancers might perceive the world differently because they have a special capacity to simulate what they observe. This theory does not imply that we can understand actions only if we have already performed them. Were that the case, the moonwalk would be uninterpretable.The theory suggests only that prior experience amplifies the ability to simulate others' actions.

Although researchers have not yet tested this idea directly with dancers, recent studies of athletes provide some preliminary support for it. Imagine watching a skilled basketball player shoot free throws. Your task is to judge, as quickly as possible, whether or not each shot will go in the basket. In 2008, in an analogous approach using videos, Salvatore Aglioti and colleagues at the University of Rome compared the judgments of professional basketball players, coaches and fans. Players were far better than fans at quickly and accurately predicting whether a free throw would go in. The athletes unconsciously detected the shooter's subtle movements, such as the angle of his ankle and wrist as he released the ball.[5] Coaches, who averaged about seven years of playing experience, were better than fans but not as good as players. These results suggest that extensive practice—*embodied knowledge*—changes our ability not just to execute, but also to observe.

Rapid Training Enhances Effects

Ballet and capoeira dancers train for years. Can we measure changes in the AON after shorter training periods? If the answer were yes, such a finding would suggest that the AON is also involved in the kind of observational learning that we use at a moment's notice to pick up new skills. To test this, Emily Cross from my laboratory trained a troupe of modern dancers on a new dance piece over ten weeks and tracked changes in AON activity.[6] While their brains were scanned using fMRI, the dancers watched short video segments of their instructor performing one dance piece that they rehearsed daily and a second piece that they had seen but not practiced. As they gained physical experience in the dance they practiced and watched the video of their instructor, activity in the AON increased. Moreover, while watching the video segment of the rehearsed dance, the better a dancer thought he or she could execute a part of the dance, the greater his or her AON activity. This finding provides new evidence that links physical competence and simulation within the AON.

We next investigated whether the AON is modified only by physical practice or also by observing an action. We trained undergraduates with limited dance experience on a set of challenging dances using a variation of *Dance Dance Revolution*. Each dance consisted of a sequence of stepping patterns associated with a specific song; arrows provided foot-placement cues.[7] Participants learned some dances through physical practice and other dances solely by observing the instructions. Follow-up tests showed that the benefit from learning by observing was never as strong as advantages derived from physical practice.

These participants also were scanned while they watched segments of the different dances. Activity in the AON was greater when they watched dances that they had practiced physically compared with dances to which they had not been exposed; this is consistent with findings from the other fMRI dance studies. But this experiment revealed something new: *Dances learned by observation alone triggered AON activity, but dances learned via physical practice stimulated greater activity*. We also found that adding a physical model (including an image of a dancer performing the particular dance piece) augmented brain activity compared with a video that used only symbolic instructions (arrows).[8] These findings led us to conclude that the AON is a general-purpose observational learning network for simulating actions, and it is cued by both physical and symbolic models.

Action Observation as an Engine for Learning

The AON experiments provide glimpses into a brain system that is exquisitely tuned to learn and to understand physical knowledge. Such insights from cognitive neuroscience help to identify learning principles important to education policy and practices; they form the very basis of the new (and growing) academic field of neuroeducation. Our society places great emphasis on academic success within a narrow set of areas (math, reading or higher IQ). This makes it tempting to apply a narrow translational framework whereby the value of dance, music and other physical arts depends only on the degree to which these pursuits make a student more successful in the desirable academic areas.

Within this narrow framework, some evidence suggests that training children in music modestly improve their IQ scores.[9] Investigators, including me, who are participating in a Dana Foundation-supported research consortium, are identifying some of the many factors that likely contribute to these modest improvements. For instance, Michael Posner at the University of Oregon is showing that children who are interested in learning music focus their attention on it. They can then apply their improved attention skills to learning to read, write or solve math problems.[10]

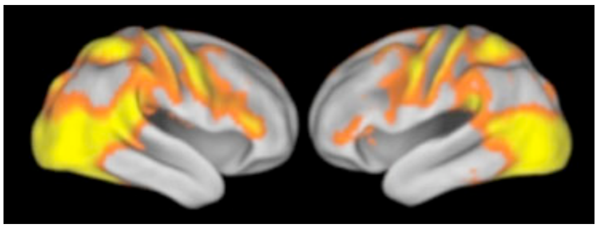
A more challenging question is whether learning in one area transfers to others. For example, Elizabeth Spelke at Harvard University is testing the hypothesis that improved understanding of the complex spatial and temporal patterns of music could generalize to improved abilities in abstract spatial reasoning, which underlies some mathematics—especially geometry. In this model of studying whether music training transfers to improved abilities in spatial reasoning, though, there is no examination of whether the physical skills involved in the training might contribute to the potential effects.

Scientists test whether arts learning transfers to other cognitive areas using behavioral measurements in children before and after they receive arts training. We know a lot about brain areas activated in both pursuit of the arts and in cognition. Two important tasks are to figure out how to use the growing wealth of functional imaging data to extend ideas about crossover effects and to see if this new information might further influence education theory. For example, brain areas activated during mathematical reasoning overlap strikingly with those active when watching dancers (for example, components of the AON). Can we then conclude that learning to dance well translates to mathematical pursuits because the same brain area is involved in both? Though plausible, this idea lacks sufficient behavioral evidence to merit a change in education practice. It is likely an oversimplification that doesn't accommodate for the degree to which specific brain areas are actually part of much larger and more complex neural networks. This example reminds us that the pathway from neuroscience insight to educational practice will be more complicated than a linear translation of principles.

Conventional K–12 education practitioners emphasize reading, writing and mathematics, which supposedly will produce progressive parallel development in cognitive capacities such as reasoning, abstraction and semantic knowledge. School administrators add physical education to the curriculum mostly for its health benefits. At the same time, they are cutting courses focused on material or physical knowledge, such as machine or wood shop, electronics, music, dance and theater arts. This approach belies an assumption that anyone with sufficient cognitive abilities can gain material or physical knowledge if they just put their mind (or hands) to it; as long as children are smart in the head, the hands will follow. This false dichotomy between knowing (as defined by cognitive models) and doing dominates contemporary education policy and practice.

Physical Mastery, Motivation and Social Intelligence

Our AON research suggests three ways that learning in the arts—and in physical skills more generally—remains vital to educational practice.



Functional magnetic resonance imaging shows brain areas that were more active when 24 healthy participants watched modern dancers in short video clips and tried to infer how the dancer felt (happy, sad or nervous) based on body movements alone. The activity identifies the brain's action observation network. (Courtesy of Scott T. Grafton.)

First, studies of the AON and observational learning remind us that much knowledge comes from the overwhelming challenges of mastering the material world, be it changing a flat tire or playing a song on a musical instrument. Physical knowledge need not be subordinate to cognitive training for a child to receive the best education. Experiential knowledge is essential for creating great surgeons and truck drivers alike. It drives creativity and innovation in the sciences, as anyone who has ever built a novel measurement device, developed a new laboratory assay or handled a sample of any kind can attest. The bulk of this knowledge stems from observational and imitative learning, which the AON facilitates. Success in solving problems in the real world, not the virtual or symbolic world, gives most people their deepest joys; ultimately, we researchers would like to understand how.[11]

The second benefit of teaching arts and physical knowledge is based on harnessing passion. The hunger to learn these skills is a source of profound motivation that can spread to all aspects of a learner's life and augment performance generally. Teachers see this every day. We are only just beginning to understand how the brain creates positive motivation. Our research also has focused on defining brain systems that are driven by passionate interests, physical skills and how they interact in the AON.

For example, in one experiment, we briefly flashed a string of letters on a computer screen and asked participants to decide if the letters constituted a word (e.g., *world*) or a nonword (e.g., *owrdl*). In a sneaky manipulation, we also flashed a word that described either an activity the participant was passionate about, such as *guitar*, or an activity about which he or she did not feel strongly. This word appeared just before the word/nonword challenge, and it happened so quickly that the person was not consciously aware of it. Nevertheless, participants were faster and more accurate at the word/nonword task when their "passion" word appeared.[12] We also tested this effect in patients with Parkinson's disease and found that "treatment" with these subliminal cues can improve performance in multiple tasks for about 20 minutes. Furthermore, brain scans showed that the AON shapes and modifies the interaction between word priming and the subsequent word/nonword recognition task. These results show that *passions can be a source of motivation that spreads to a broad range of cognitive challenges*. A skillful teacher thus might be able to use the arts to harness students' enthusiasm and help spread it to other subjects—a point Michael Posner makes in his recent *Cerebrum* article, "How Arts Training Improves Attention and Cognition."

Third, studies in the arts amplify learning that supports social intelligence. Specifically, the emotional scaffolding that supports empathy and perspective is linked in part to how we perceive and interpret others' actions. In recent work, we have been able to show direct involvement of the AON not only in what people are doing, but also in how they feel as they do something. When you watch someone walk down the street, your AON is highly tuned in to his or her body language—signals that suggest whether the person is happy or sad, for example. This initial research inspires future studies that should be able to determine the degree to which the AON can change as emotional intelligence develops, as well as the potential for education in the arts to accelerate this process.

Comments

Movement and Learning
KATHRYN SIMON
10/19/2009 10:28:36 AM
I am interested in being in touch with any dancers or teachers of movement who are working with or want to work with students as an adjunct to learning in general. I can be reached at Simonk@newschool,edu. Thanks Kathryn Simon

Dance and Art Saved Me from Brain Injuries(2)
NATASHA "Z" ZAZHINNE
10/5/2009 7:06:02 PM
1998--I got toxic encepalopathy--MD's said permanently blind, permanently brain-damaged, permanently disabled. Trained from childhood by an MD med prof father in how the body worked--and by world-class dancers in how to work the body-mind-spirit--I eschewed the drugs to treat symptoms and followed instinct, training, and lifelong habit. Today I'm WELL and I can SEE. Blind for 5.5 years. Glad you brain experts are getting onto how important Art and Dance are to HEALING. I write about it--and will be reading the "Brain Injuries" section of my book on my blog later this week. uncommonsensewithz.blogspot.com

Dance and Art Saved Me from Brain Injuries
NATASHA "Z" ZAZHINNE
10/5/2009 7:01:31 PM
I grew up in the world of Art, trained by world-class dancers in how to work the body and a Med Prof father in how the body (and brain) worked. 1998--MD's said I was "permanently blind, permanently brain-damaged, permanently disabled" from toxic encepalopathy. I eschewed drugs, did the Dance and Body-Mind work I'd done all my life. That, my lifelong-ingrained Wellness Lifestyle, neurofeedback, O2 therapies--including therapeutic grade essential oils and HBOT, let me get my sight back--after 5.5 years--and get WELL again. www.zeeva.net

Dance, Learning etc.
STEVEN CORDOVANO
10/5/2009 3:10:53 PM
Interesting article. I have read that in India people who want to pursue careers in the arts must first learn dance, which is an interesting concept. Not that a person who wants to play guitar has to master dance, but as a musician myself, I can see that a person who has no connection with his or her body might be able to read music and play perfunctorily, but probably could not channel the sensitivity needed to perform at an inspired level. This might tie in with the passion to learn in general.

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