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IS A REVOLUTION COMING?

Movement, Exercise, and Learning

> The sedentary character of modern life is a disruption of our nature, and it poses one of the biggest threats to our continued survival.
>
> (Ratey, 2008)

When I was 15, I went out for the varsity basketball team. My brother, who was the best player in the history of our high school, had graduated, so I thought there was room now for a new Doyle on the team. I also decided to try out because I knew I needed to get in better shape. Although I never approached my brother's success in basketball, I did discover something that has helped me to be a better learner my whole life. I discovered that when I ran a lot (and we ran *a lot*), I was always able to focus on school activities, particularly homework, better than when I was not in basketball season. I don't want you to think that somehow, at age 15, I knew exercise was important for learning; I didn't. I just recognized that it was easier to do my homework after basketball practice than it was other times of the year. Forty-five years later, I now have a scientific explanation about why my studying was easier: It was the neurochemicals serotonin, dopamine, and norepinephrine and the protein brain-derived neurotrophic factor (BDNF) that my brain released during my running that helped to improve my focus and learning (Ratey, 2008).

This chapter explores how exercise and movement play a vital role in learning, a role so significant that, regardless of how difficult it might be to find ways to integrate it into our learning protocols, it must be done at all levels of education.

What Science Says About Exercise and Learning

If we step back 500 million years ago, when the first nerve cells developed, we would discover that the original need for a nervous system was to coordinate movement so an organism could find food instead of waiting for the food to come to it. The first animals to experience movement had a tremendous advantage over sponges, for example, which had to wait brainlessly for dinner to arrive (Franklin Institute, 2004). Though a great deal of our evolutionary history remains shrouded in controversy, one thing paleoanthropologists agree on is that we moved (Medina, 2008). Anthropologist Richard Wrangham says that, a few hundred thousand years ago, men moved about 10 to 20 kilometers a day and women moved about half of that each day. Our brains developed while we were moving. In fact, it would be fair to say that our brains developed to solve problems of survival while humans were outdoors and in constant motion (Medina, 2008, p. 32).

Flash-forward to 1995 and Carl Cotman, director of the Institute for Brain Aging and Dementia at the University of California at Irvine, discovers that exercise sparks the master molecule of the learning process: brain-derived neurotrophic factor (BDNF), which is a protein produced inside nerve cells when they are active. BDNF serves as fertilizer for brain cells, keeping them functioning and growing; it also spurs the growth of new neurons (Ratey, 2008). With this discovery, Cotman showed a direct biological connection between movement and cognition (as cited in Ratey, 2008, p. 43). What Cotman first discovered in 1995 has blossomed into a revolution in terms of scientific study. In 1995, barely a handful of studies on BDNF existed. Today, more than 6,000 papers have been written on BDNF. John Ratey, author of *Spark: The Revolutionary New Science of Exercise and the Brain* (2008), referred to BDNF as "Miracle Grow for the brain." Ratey said, "Exercise strengthens the cellular machinery of learning by creating BDNF which gives synapses the tools they need to take in information, process it, associate, remember it and put it in context" (p. 45). UCLA neuroscientist Fernando Gómez-Pinilla's research shows that a brain low on BDNF shuts itself off to new information (Ying, Vaynman, & Gomez-Pinilla, 2004).

How Does Exercise Help Learning?

> *No matter your age, it seems, a strong, active body is crucial for building a strong, active mind.* (Carmichael, 2007)

Exercise increases synaptic plasticity by directly affecting synaptic structure and potentiating synaptic strength, and by strengthening the underlying systems that support plasticity, including neurogenesis, metabolism, and vascular function (Cotman, Carl, Berchtold, & Christie, 2007). This very technical explanation means that exercise helps all of the key brain functions needed to make learning easier. Human and nonhuman animal studies have shown that aerobic exercise can improve many aspects of cognition and performance (Hillman, Erickson, & Kramer, 2008). In a 2011 *Newsweek* article, neuroscientist Yaakov Stern of Columbia University discussed the three events that occur in our brains and enhance our cognitive capacity. The first is an increase in number of neurons or synapses. The second is higher levels of neurogenesis (new cell growth), especially in the memory-forming hippocampus. The third is increased production of BDNF, which stimulates the production of neurons and synapses (as cited in Begley, 2011). All three occur when we exercise. Exercise itself doesn't make you smarter, but it puts the brain of the learners in the optimal position for them to learn (Ratey, 2008).

By exercise, I am referring to a wide variety of activities, with the most beneficial being aerobic exercise that also involves the learning of a new skill, such as learning to play tennis, learning one of the martial arts, or even practicing a new dance step. Any movement is better than no movement when it comes to enhancing learning. Many studies show the positive effects of simple walking on improved cognitive functioning, especially in older adults (Weuve et al., 2008).

Brain-Derived Neurotrophic Factor and Exercise

Brain-derived neurotrophic factor (BDNF) is a protein that gathers in reserve pools near synapses in our brains and is unleashed when we get our blood pumping. BDNF generates new neurons, protects existing neurons, and promotes synaptic plasticity, which is generally considered the basis for learning and memory (Mattson, Wenzhen, Rugian, & Gou, 2004; Modie, 2003). In this process, a number of hormones, including insulin-like growth factor, vascular endothelial growth factor, and fibroblast growth factor from our bodies, are called into action to help the BDNF crank up the molecular machinery of learning (Ratey, 2008, p. 52). All of this brain activity results in learning that is improved on three levels.

Level One

Exercise increases the production of three very important neurochemicals involved in learning: serotonin, dopamine, and norepinephrine. These neurochemicals aid our brains in their ability to be alert, pay attention, be motivated for learning, and be positive toward learning (improve mood), and they help to enhance our patience and self-control (Ratey, 2008). As educators, we know that these abilities are crucial to successful learning. Perhaps most significant is that the areas improved by exercise are the very areas where many of our students struggle most in their learning. If our students are alert, focused, motivated, and paying attention; had positive attitudes; and could manage their in-class behaviors appropriately, it might be fair to say that we have the perfect learning situation.

Level Two

Exercise prepares and encourages nerve cells to bind to one another, which is the cellular basis for logging in new information (Ratey, 2008, p. 53). Exercise stimulates the production of new synapses, whose capacity and efficiency underlie superior intelligence (Kramer et al., 2010). Put simply, exercise makes it easier for us to grow smarter. One piece of evidence that supports this finding comes from a 1999 study done in the Naperville, Illinois, public schools, where aerobic exercise was added to the junior high school curriculum. Results show significant increases in students' test score performance, even on tests like the Trends in International Mathematics and Science Study (TIMSS), on which most often U.S. schools rank well below their worldwide counterparts. The Naperville eighth-grade students finished first in the world in science, just ahead of Singapore, and sixth in math (trailing Singapore, South Korea, Taiwan, Hong Kong, and Japan) (Ratey, 2008, p. 14). Yes, these were middle-class youngsters from a good school system, but they did not match neighboring schools in per pupil funding or in average scores on college entrance exams (SAT or ACT). There was nothing to suggest that this kind of accomplishment was in their future. TIMSS is the same test in which only 7% of U.S. students even scored in the top tier. An additional positive, albeit unexpected, finding from the study showed a 66% decline in behavior problems and suspensions following the introduction of aerobic activities at the school. This was associated with the positive effect that the neurochemicals of serotonin, dopamine, and noradrenalin had on students' ability to control their behavior.

Level Three

Exercise also spurs the development of new nerve cells, in a process called neurogenesis, from stem cells in the hippocampus (Ratey, 2008, p. 53). Prior to 1998, there was no conclusive evidence that our brains even made new cells. Once proof was established (Eriksson et al., 1998), scientists have been working to uncover what these new brain cells actually do. One discovery is that new cells spawned during exercise are better equipped to spark long-term potentiation (LTP), which is a long-lasting enhancement in signal transmission between two neurons that results from stimulating them synchronously. LTP is widely considered to be one of the major cellular mechanisms that underlie learning and memory (Cooke & Bliss, 2006). Princeton neuroscientist Elizabeth Gould suggested that these new cells play a role in hanging onto our conscious thoughts, while the prefrontal cortex decides if they should be wired in as long-term memories (Gould, 2008). Columbia University Medical Center neurologist Scott Small and Salk Institute neurobiologist Fred Gage (Small & Gage, 2007) found that the new neurons created by exercise cropped up in only one place: the dentate gyrus of the hippocampus, an area that controls learning and memory. The hippocampus is especially responsive to the effects of BDNF, and exercise seems to restore it to a healthier, "younger" state (Small & Gage, 2007). At this time, research continues as to the exact role(s) neurogenesis plays in our learning. What we do know for certain is that exercise promotes neurogenesis.

How Much Exercise Is Needed?

How much exercise is needed to experience the learning benefits already described in this chapter? This question has not been fully answered. One thing that is clear, however, is that trying to learn something that is difficult or complex *while* engaged in aerobic activity is a bad idea. When engaged in aerobic activity, blood flows away from the prefrontal cortex and hampers executive functioning. Once exercise is completed, however, blood flow returns to the prefrontal cortex almost immediately, and this is an ideal time for learning to take place. This is an important finding to share with students. Despite my best efforts to help my students understand the learning benefits of exercise, I still find some who think that, if exercise is good for learning, then trying to study during exercise must be a good idea.

Ratey suggests that 30 minutes of exercise in which our heart rates reach the appropriate levels for our age, four to five times a week, is a good baseline. The appropriate heart rate level is different for all of us. To figure mine, I subtract my age, which is 59, from 220, which it gives me my maximum heart rate per minute of 161. I should reach 60 to 70% of that level while exercising. In addition, if I can include in my aerobic-level workout the learning of a new skill, such as a new dance or martial art, this new skill would be even more beneficial for my brain (as cited in Begley, 2011). A study completed in 2007 showed that even one aerobic session lasting 35 minutes improved mental processing speeds and cognitive flexibility in adults (Carles et al., 2007). Neuroscientist Art Kramer and his colleagues at the University of Illinois found that a year of aerobic exercise can give a 70-year-old the connectivity of a 30-year-old, improving memory, planning, navigating of ambiguity, and multitasking (Kramer et al., 1999). In a study done on young and middle-aged adults, the authors found that physical activity may be beneficial to cognition during early and middle periods of the human lifespan and may continue to protect against age-related loss of cognitive function during older adulthood (Hillman et al., 2008). Neuroscientist Khatri Blumenthal and his colleagues reported that exercise had its beneficial effect in specific areas of cognitive function that are rooted in the frontal and prefrontal regions of the brain. The implications are that exercise might be able to offset some of the mental declines we often associate with the aging process (Blumenthal et al., 2001).

Using Exercise in School

When new ideas about how learning can be improved come along, there is always some reticence to jump on board. Educators have been led down paths to nowhere before. A prime example is in the right brain/left brain learning protocols that turned out to be unsupported by research findings but still found their way into all kinds of schools (Taylor, 2009). In the case of exercise, the research is solid, and implementation has been underway for the last 5 years. Next I describe several studies that show how exercise in schools is improving learning.

City Park High School in Saskatoon, Canada, put treadmills and exercise bikes in a math classroom; before doing any math, the kids strapped on their heart-rate monitors and did 20 minutes of moderate-intensity cardiovascular exercise. This is an alternative school for students with learning difficulties, and over half the students have attention deficit hyperactivity disorder (ADHD). They couldn't sit still, many had behavioral problems, and they had difficulty learning. Within 5 months nearly all of the students had jumped a full letter grade in reading, writing, and math. After doing the exercise, the students were suddenly able to sit still and focus on what they were learning, and they were able to understand what they were being taught. The exercise altered their brain chemistry enough to make learning possible, *and* it greatly improved their behavior (Gurd, 2009).

In 2007, neuroscientist Charles Hillman described how he put 259 Illinois third-graders and fifth-graders through standard physical education routines such as push-ups and a timed run, and he measured their body mass. Then he checked their physical results against their math and reading scores on the Illinois Standards Achievement Test. The more physical tests they passed, the better they scored on the achievement test. The effects appeared regardless of gender and socioeconomic differences, so it seems that, regardless of his or her gender or family income, the fitness of a child's body and mind are closely linked (Hillman & Castelli, 2007a).

The bigger the dose of exercise, the more it can pay off in academic achievement. In a 2007 study, researchers found that children ages 7 to 11 who exercised for 40 minutes daily after school had greater academic improvement than children of the same age who worked out for just 20 minutes (Castelli, Hillman, Buck, & Erwin, 2007).

Getting Exercise and Movement in Higher Education

The challenge that confronts those of us in higher education is how we use these findings about exercise, movement, and learning to optimize our students' learning. We cannot turn our backs on this research simply because our schools' physical facilities are not conducive to letting students move around while learning. We need to approach this problem with the same creative, imaginative problem-solving processes that we constantly say we want our students to learn to use in their own lives. We talk the problem-solving talk to our students all the time; now we need to walk the walk.

In chapter 1, I briefly discuss a study at Grand Valley State University in Michigan where students sat on exercise balls instead of chairs while taking their science courses. Although qualitative in nature, findings were overwhelmingly positive because students reported that they felt they were better focused and learned more. This is an example of a starting place for introducing more movement into higher education. Starting in the fall of 2011, I will be doing a small research project using balance balls in my first-year reading courses. I am interested in finding out if the balance balls will help my students to stay more focused and on-task longer when reading, which is always a problem for them. In a recent visit to San Jacinta Community College in Houston, I was pleasantly surprised to see minibicycles under each of the computer tables in their students' computer lab. The coordinator said that the students enjoy the movement while working on their assignments and reported that they stay more engaged for longer periods of time.

One question I ask faculty members as I visit campuses is, How can we get more movement into our students' learning? The following are a few of their suggestions:

1. **Moving discussions.** Rather than have students sit and talk, have them walk and talk. It works by assigning students discussion questions and asking them to take a walk for 15 to 20 minutes and talk about the issues assigned. When they return, they sit down, record their findings, and then share them with the other groups.
2. **Walking critiques.** Have students complete a set of problems or answered questions on whiteboards or newsprint and then post the findings around the classroom. Students then walk around the room critiquing the findings of their peers, adding or changing answers as they walk along. When the critiques are completed, a discussion is held to determine the best answers based on the critiquing process.
3. **Guided tour.** Using the museum or national parks model of a walking tour, course lessons are taught while walking and observing items relevant to the course information. This technique works well in art, ecology, geography, architecture, and many other subjects.
4. **Allowing students to stand and stretch when needed during class.** I allow my students to do this any time they feel they are losing their attention. I have not found it to be disruptive, and I know that no reading is accomplished without full attention.
5. **Taking more breaks during lectures.** A significant number of studies prove a shortening of attention spans, especially since the flooding of the marketplace with personal media tools and toys (Swing, Gentile, Anderson, & Walsh, 2010). One way to help our students to focus is to let them move and breathe for periods of time as short as 30 seconds. Our brains need a lot of oxygen to function well, so letting students stretch, move, and breathe is good for learning. In addition, when a new concept has been introduced, students need an opportunity to practice thinking in terms of that concept. Letting them rise, stretch, and think about what they have just learned by generating their own examples of the concept, summarizing it, thinking of an exam question for it, or explaining it to someone else is part of the mind's natural processes of learning (Middendorf & Kalish, 1996).

Selling Our Students on the Value of Exercise

The more time I spent reading the research on exercise and learning, the more it became clear to me that I had to take meaningful actions. One such action was to begin my own aerobic exercise program that included learning new skills as part of the workout. The second was to work very hard to sell my students on the importance of putting exercise into their daily lives. To be honest, I have done much better on the latter of these two actions. I now do a 1-hour presentation in all of my classes about the relationship among exercise, movement, and learning. I detail the science behind it, showing how exercise leads to enhanced learning. I use the example of the junior high students from Naperville, Illinois, who finished first in the world in science on the TIMSS test after aerobics were introduced to the daily school activities. I have posted the slides I use from this presentation on my website, http://learnercenteredteaching.wordpress.com, for anyone who would like to have a similar discussion with their students. I have also created a video, available on YouTube, called "Exercise and College Learning" that can be shown to students. This research has the potential to improve learning in higher education significantly, and we have an obligation not only to share it with our students, but to sell it to them as a product they cannot do without.

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