Movement and Learning

For decades, educators, researchers and scientists seemed to believe that thinking was thinking and movement was movement, and each was as separate as could be. In recent years, with the advancement of neuroimaging techniques, more studies and research have emerged to show strong relationships between physical education, movement activities, and improved cognition. The science now provides a better understanding of the critical “windows of opportunity” to help us identify when positive experiences may be most beneficial in the developmental process. It demonstrates that movement can be an effective cognitive strategy to (1) strengthen learning, (2) improve memory and retrieval, and (3) enhance learner motivation and morale.

Why is this important?

Because movement is a natural part of the school day, and that movement *will influence* the brains of students. It is essential that we explore the ways we are shaping students' brains. To do so, let's look at some anatomical, imaging, cognitive, and functional studies that suggest we ought to be supporting more movement in the learning process, not less.

New Perspectives on Early Brain Development

The “wiring” of the brain is an amazing phenomenon of precision considering that the mature brain contains in excess of 100 billion neurons that are intricately connected with one another in ways that make possible the amazing functions underlying human behaviour.

Many years ago researchers believed that the “neural wiring” for each person was primarily “programmed” by one’s genetic blueprints, much like the wiring of a new house before being occupied. However, the recent view is that while the main circuits may be prewired, such as for breathing, control of heart beat, and reflexes, other basic pathways are quite rudimentary, containing trillions of finer “unprogrammed” tentative connections. These connections are dependent upon stimulation from the environment and experience in the environment. It is this stimulation that completes the architecture of the brain, or what you have commonly heard of in recent times, neuroplasticity.

Scientists now believe that to achieve the precision of the mature brain, stimulation in the form of movement and sensory experiences during the early developing years is necessary (Greenough & Black, 1992; Shatz, 1992). Experience appears to exert its effects by strengthening and bonding synapses, which are the connections that are made between neurons. Connections that are not made by activity, or are weak, are “pruned away,” much like the pruning of dead or weak branches of a tree. If the neurons are used, they become integrated into the circuitry of the brain. Due to differences in experience, not even identical twins are wired the same (Chugani, 1998).

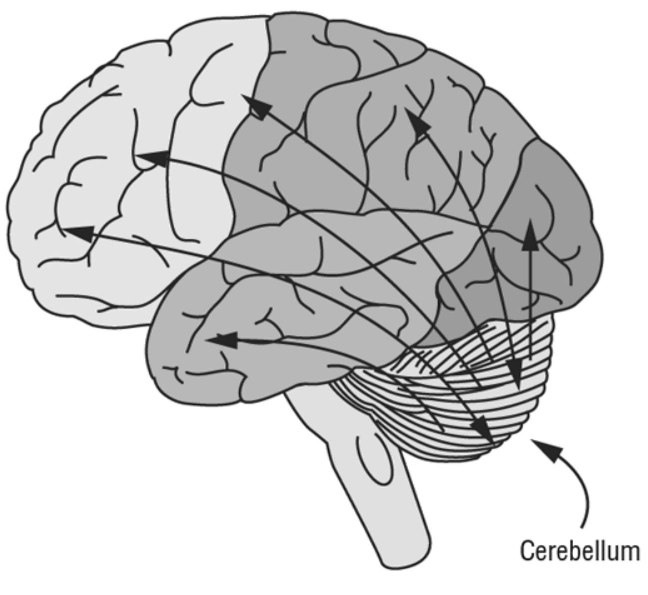
The primary basis for the importance of movement and sensory experiences was derived from studies which compared brain structures of animals raised in various environmentally normal, deprived, and enriched settings. The enriched settings provided the opportunity to interact with toys, treadmills, and obstacle courses. Overall, such research has led to the conclusion that stimulation is a significant factor in overall brain development (Jones & Greenough, 1996; Kempermann & Gage, 1999). Animals placed in enriched environments had brains that were larger and contained more synaptic connections.

Today, the evidence has become a groundswell, and most neuroscientists agree that movement and cognition are powerfully connected.

Anatomical Evidence

The area of the brain most associated with motor control is the cerebellum. It's located in the back of the brain, just under the occipital lobe, and is about the size of a small fist. The cerebellum takes up just one-tenth of the brain by volume, but it contains *nearly half* of all its neurons (Ivry & Fiez, 2000). This structure, densely packed with neurons, may be the most complex part of the brain. In fact, it has some 40 million nerve fibers—40 times more than even the highly complex optical tract. Those fibers feed information from the cortex to the cerebellum, and they feed data back to the cortex. In fact, most of the neural circuits from the cerebellum are "outbound," influencing the rest of the brain (Middleton & Strick, 1994). Peter Strick at the Veteran Affairs Medical Center of Syracuse, New York, has documented another link. His staff has traced a pathway from the cerebellum back to parts of the brain involved in memory, attention, and spatial perception. Amazingly, the part of the brain that processes movement is the same part of the brain that processes learning (see Figure 4.1).

Figure 4.1. Links Between the Cerebellum and Other Parts of the Brain



Information travels to and from the cerebellum, the brain's center of motor control, and other parts of the brain involved in learning, but most of the neural circuits are outbound.

Evidence from Imaging Techniques

New data, primarily from studies using functional magnetic resonance imaging (fMRI), have provided support for parallel roles of cognitive structures and movement structures such as the cerebellum. We learn to predict (think about) our movements before we execute them (move) so that we control them better (Flanagan, Vetter, Johansson, & Wolpert, 2003). This ability suggests that all motor activity is preceded by quick thought processes that set goals, analyze variables, predict outcomes, and execute movements. Pulling this off requires widespread connections to all sensory areas.

Various studies support the relationship between movement and the visual system (Shulman et al., 1997), movement and the language systems (Kim, Ugirbil, & Strick, 1994), movement and memory (Desmond, Gabrielli, Wagner, Ginier, & Glover, 1997), and movement and attention (Courchesne & Allen, 1997). These studies do not suggest that there is movement in those functions. But they suggest a relationship with the cerebellum in such mental processes as predicting, sequencing, ordering, timing, and practicing or rehearsing a task before carrying it out. The cerebellum can make predictive and corrective actions regardless of whether it's dealing with a gross-motor task sequence or a mentally rehearsed task sequence. In fact, the harder the task you ask of students, the greater the cerebellar activity (Ivry, 1997). Taken as a whole, a solid body of evidence shows a strong relationship between motor and cognitive processes.

Cognitive Evidence

Just how important is movement to learning? The vestibular (inner ear) and cerebellar (motor activity) system is the first sensory system to mature. In this system, the inner ear's semicircular canals and the vestibular nuclei are an information-gathering and feedback source for movements. Impulses travel through nerve tracts back and forth from the cerebellum to the rest of the brain, including the visual system and the sensory cortex. The vestibular nuclei are closely modulated by the cerebellum and also activate the reticular activating system, near the top of the brain stem. This area is critical to our attentional system, because it regulates incoming sensory data. This interaction helps us keep our balance, turn thoughts into actions, and coordinate movements. That's why there's value in playground activities that stimulate inner-ear motion, like swinging, rolling, and jumping. A complete routine might include spinning, crawling, rolling, rocking, tumbling, and pointing.

Functional Evidence

Currently, the MEDLINE database shows more than 33,000 scientific articles on the topic of exercise, and the vast majority of them confirm its value. One study showed that people who exercise have far more cortical mass than those who don't (Anderson, Eckburg, & Relucio, 2002). Simple biology supports an obvious link between movement and learning. Oxygen is essential for brain function, and enhanced blood flow increases the amount of oxygen transported to the brain. Physical activity is a reliable way to increase blood flow, and hence oxygen, to the brain.

In William Greenough's experiments at the University of Illinois, rats that exercised in enriched environments had a greater number of connections among neurons than those that didn't. They also had more capillaries around the brain's neurons than sedentary rats (Greenough & Anderson, 1991). Solid evidence suggests that even going for brisk walks can elicit this state of arousal—meaning an increase in heart rate, EEG activity, and more excitatory active brain chemicals (Saklofske & Kelly, 1992). In fact, if you haven't yet taken a break from reading this riveting chapter, you might stand and stretch for a moment. Why? Standing can raise heart rate (hence, blood flow) by as much as 5 to 8 percent in just seconds (Krock & Hartung, 1992). And finally, here's a powerful research finding: evidence from animal studies indicates that voluntary exercise influences gene expression to improve learning and memory (Tong, Shen, Perreau, Balazs, & Cotman, 2001). This improved pattern of gene expression enhances many factors that support the encoding and transfer of data, synaptic structure, and the activity and plasticity of neurons. All of these processes facilitate learning.

Support for Recess, Play, and Physical Education

Researcher Terrence Dwyer is one of many who have conducted multiple studies suggesting that exercise supports success in school. His research found that exercise improves classroom behaviour and academic performance (Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001) and that even when an experimental group got four times more exercise per week than a control group of their peers (375 minutes versus 90 minutes), their “loss” in studying time did not translate into lower academic scores (Dwyer, Blizzard, & Dean, 1996). His research further revealed that social skills improved in the groups who exercised more. Other research (Donevan & Andrew, 1986) has found that students who are engaged in daily physical education programs consistently show not just superior motor fitness, but better academic performance and a better attitude toward school than their students who do not participate in daily P.E.

Additional Benefits for Special-Needs Learners

Many teachers have found that programs that include movement help learners with special needs. Several hypotheses may explain this phenomenon. Many special-needs learners are stuck in counterproductive mental states, and movement is a quick way to change them. Second, movements, such as those involved in playing active games, will activate the brain across a wide variety of areas. It may be the stimulation of those neural networks that helps trigger some learning. For other students, it may be the rise in energy, the increased blood flow, and the amines that put them in a better mood to think and recall. Some routines that call for slower movement can do the reverse, calming down students who are overactive, hence supporting a state of concentration.

A study by Reynolds and colleagues (2003) found that children with dyslexia were helped by a movement program. Those in the intervention group showed significantly greater improvement in dexterity, reading, verbal fluency, and semantic fluency than did the control group. The exercising group also made substantial gains on national standardized tests of reading, writing, and comprehension in comparison with students in the previous year.

Summary

Strong evidence supports the connection between movement and learning. Evidence from imaging sources, anatomical studies, and clinical data shows that moderate exercise enhances cognitive processing. It also increases the number of brain cells. . Through the use of movement experiences, educators can stimulate problem-solving abilities, critical thinking, and reinforce a variety of academic concepts. And as a bonus, it can reduce childhood obesity. Movement activities should become as important as so-called “book work.”

References

Begley, S., (Spring/Summer 1997). How to build a baby’s brain. Newsweek Special Issue.

Chugani, H.T. (1998). A critical period of brain development: Studies of cerebral glucose utilization with PET. Preventive Medicine, 27, 184-188.

Coveney, P., & Highfield, R. (1995). Frontiers of complexity: The search for order in a chaotic world. New York: Fawcett Columbine.

Diamond, M., & Hopson, J. (1998). Magic trees of the mind: How to nurture your child's intelligence, creativity, and healthy emotions from birth through adolescence. New York: Dutton.

Fischer, K.W., & Rose, S.P. (1998). Growth cycles of brain and mind. Educational Leadership, 56 (3), 56-60.

Greenough, W. T., & Black, J. E. (1992). Induction of brain structure by experience: Substrates for cognitive development. In M. Gunnar & C. Nelson (Eds.), Minnesota Symposia on Child Psychology. Vol. 24, Developmental Behavioral Neuroscience (p. 155-200).

Jones, T., & Greenough, W. T. (1996). Ultrastructural evidence for increased contact between astrocytes and synapses in rats reared in a complex environment. Neurobiology of Learning & Memory, 65 (1), 48-56.

Kempermann, G., & Gage, F. H. (1999). New nerve cell for the adult brain. Scientific American, May, 48-53.

Nash, M. (1997, February 3). Fertile minds. Time, 149, 49-56.

National Association for Sport and Physical Education. (2002). Active Start: A Statement of Physical Activity Guidelines for Children Birth to Five Years. Reston, VA: NASPE.

Shatz, C. (1992). The developing brain. Scientific American. September, 3-9.

Sylwester, R. (1995). A celebration of neurons: An educator's guide to the human brain. Alexandria, VA: ASCD.

Ivry, R.B., and Fiez, J.A. (2000). Cerebellar contributions to cognition and imagery.

Middleton FA, Strick PL. (1994) Anatomical evidence for cerebellar and basal ganglia involvement in higher cognitive function.

Flanagan JR, Vetter P, Johansson RS, Wolpert DM (2003) Prediction precedes control in motor learning

Reynolds, Nicolson, & Hambly (2003) Science, sophistry and 'commercial sensitivity': Comments on 'evaluation of an exercise-based treatment for children with reading difficulties'

Tong, L., Shen, H., Perreau, V.M., Balazs, R., & Cotman, C.W. (2001). Effects of exercise on gene-expression profile in the rat hippocampus.

Dwyer T, Blizzard L, Dean K. (1996) Physical activity and performance in children.

Dwyer T., Sallis JF, Blizzard L, Lazarus R, Dean K. (2001) Relation of academic performance to physical activity in children

Desmond, J. E., Gabrieli, J. D., Wagner, A. D., Ginier, B. L., & Glover, G. H. (1997). Lobular patterns of cerebellar activation in verbal working-memory and finger-tapping tasks as revealed by functional MRI.

Kim SG[1], Uğurbil K, Strick PL (1994) Activation of a cerebellar output nucleus during cognitive processing

Anderson, Eckburg, & Relucio (2002) Alterations in the thickness of motor cortical subregions after motor-skill learning and exercise

Courchesne & Allen (1997) Attentional activation of the cerebellum independent of motor involvement