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This chapter is an introduction to how the learning process changes the brain, with special attention to the facilitative role of the adult educator/mentor.

Neuroscience and Adult Learning

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Recent work on brain development and learning suggests that the most effective adult educators may be unwitting neuroscientists who use their interpersonal skills to tailor enriched environments that enhance brain development. The brain is a social organ innately designed to learn through shared experiences. Throughout the life span, we all need others who show interest in us, help us feel safe, and encourage our understanding of the world around us. Brains grow best in this context of interactive discovery and through cocreation of stories that shape and support memories of what is being learned. Although many teachers consciously focus on *what* they are teaching, the evolution and structure of the brain suggests that *who they are* may be far more important to their students' learning.

As teachers and therapists ourselves, we are especially interested in how relationships of all kinds initially shape the brain during childhood and reshape the brain later in life. As people move through the stages of life, the brain also passes through various ways of perceiving, organizing, and learning about the world. As a result, the topic of learning (that is, the "what") and the nature of the student-teacher relationship are transformed as the adult student and teacher/mentor join together in a process that changes both of their brains.

Plasticity and Learning

The brain has been shaped by evolution to adapt and readapt to an ever-changing world. The ability to learn is dependent on modification of the brain's chemistry and architecture, in a process called "neural plasticity."

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Neural plasticity reflects the ability of neurons to change their structure and relationships to one another in an experience-dependent manner according to environmental demands (Buonomano and Merzenich, 1998; Trojan and Pokorny, 1999). When rats are raised in a complex and challenging environment, their brains increase in the size of the cortex, the length of neurons, the number of synapses, and the level of neurotransmitters and growth hormones (Diamond, Krech, and Rosenzweig, 1964; Guzowski, Setlow, Wagner, and McGaugh, 2001; Ickes and others, 2000; Kempermann, Kuhn, and Gage, 1998; Kolb and Whishaw, 1998). The benefits of stimulating environments are hardly reserved for the young. When adult rats are exposed to training and enriched environments, the effects of earlier nervous system damage and genetically based learning deficits can be ameliorated (Altman, Wallace, Anderson, and Das, 1968; Kolb and Gibb, 1991; Schrott and others, 1992; Schrott, 1997; Schwartz, 1964; Will and others, 1977). Although it is not possible to do such invasive research with humans, there is much evidence to suggest that our brains react in the same manner.

Studies with birds have demonstrated that the ability to learn their "songs" can be enhanced when exposed to live singing birds as opposed to tape recordings of the same songs (Baptista and Petrinovich, 1986). Other birds are actually unable to learn from tape recordings and require positive social interaction and nurturance in order to learn (Eales, 1985). Studies such as these suggest that the proper social relationship may stimulate the neural plasticity required for certain kinds of learning. It is notable that studies with high-risk children and adolescents who eventually have successful lives often mention that one or two people took an interest in them and seemed to care. This is not to be taken lightly; it underscores the fact that, like birds learning their song, people probably engage more effectively in brain-altering learning when they are face-to-face, mind-to-mind, and heart-to-heart.

In a previous book, one of us (Cozolino, 2002) outlined the aspects of successful psychotherapy that enhance neural plasticity. Although psychotherapy is a specific kind of learning, we suggest that the principles of learning are the same in the classroom and across the life span:

- A safe and trusting relationship with an attuned other
- Maintenance of a moderate level of arousal
- Activation of both thinking and feeling
- A language of self-reflection
- Coconstruction of narrative that reflects a positive and optimistic self

These shared elements appear to be necessary for treatment success in a variety of therapeutic approaches; each element finds support in neuroscience research as well. For example, a supportive and caring relationship with another person activates neural circuitry, priming it for neuroplastic processes. A moderate level of arousal—where the learner is attentive and

motivated to learn—maximizes the biochemical processes that drive the protein synthesis necessary for modifying neural structures. Though they can be disconnected by fear and anxiety, activation of both affective and cognitive circuits allows executive brain systems to coordinate their activity in support of learning. The ability to reflect on the self plays an important role in integrating multiple processing networks of memory, affect regulation, and organization. Furthermore, the narratives that people construct in dialogue support memory function and serve as a guide for future behavior. Intuitively using a combination of language, empathy, emotion, and behavioral experiments, the most successful teacher/mentors promote neural plasticity and network integration.

The Social Brain

Western science, philosophy, and education share a fundamental conception of the thinker as solitary rather than embedded within a human community. This has led to a focus on technical and abstract exploration of scientific conundra rather than exploration of lived experiences and human interactions. For example, neurobiology and neuroscience have studied the brain through scanners and on the dissection table, but until recently they neglected the fact that it flourishes best within the context of social interaction. However much one may cherish the notion of individuality and the isolated self, humans have evolved as social creatures and are constantly regulating one another's internal biological states.

The notion of the brain as a social organ emerged in neuroscience in the 1970s. Since then, researchers have been exploring and mapping the neural circuits involved in social behavior. Fields such as social neuroscience, interpersonal neurobiology, and affective neuroscience have all emerged to examine how brains interconnect with one another. Although no one module in the brain is dedicated solely to social behavior, there are multiple sensory, motor, cognitive, and emotional processing streams that come together during development to serve social and emotional behavior. It is becoming more evident that through emotional facial expressions, physical contact, and eye gaze—even through pupil dilation and blushing—people are in constant, if often unconscious, two-way communication with those around them. It is in the matrix of this contact that brains are sculpted, balanced, and made healthy. Among the many possible implications of this finding for the adult educational environment is the fact that the attention of a caring, aware mentor may support the plasticity that leads to better, more meaningful learning.

Stress and Learning

In the early part of the twentieth century, psychologists discovered that learning is maximized during a moderate state of arousal. Too little arousal,

and students are unmotivated; too much, and they are unable to sit still and attend. The biological basis for this finding has recently been discovered. It turns out that a moderate level of arousal triggers neural plasticity by increasing production of neurotransmitters and neural growth hormones, enhancing neural connections, and cortical reorganization (Cowan and Kandel, 2001; Jablonska, Gierdalski, Kossut, and Skangiel-Kramska, 1999; Myers, Churchill, Muja, and Garraghty, 2000; Pham, Soderstrom, Henriksson, and Mohammed, 1997; Zhu and Waite, 1998).

Stress in the learning environment, negative memories from past learning experiences, or problems in a student's life can also truncate learning ability. One doesn't even have to be conscious of such a stimulus for it to become a conditioned cue for fear (Morris, Öhman, and Dolan, 1998, 1999) that negatively affects learning. By contrast, successful learning may be seen as a "safe emergency"—a state of high attention but without the debilitating anxiety. If the response is a teacher's supportive caring, encouragement, and enthusiasm balanced with an appropriate level of challenge, learning is enhanced through dopamine, serotonin, norepinephrine, and endogenous endorphin production (Kilgard and Merzenich, 1998; Kirkwood and others, 1999; Barad, 2000; Kang and Schuman, 1995; Huang and others, 1999; Tang and others, 1999). In this way, the teacher's interpersonal attunement creates a biological state in the brain that makes it better able to incorporate new information.

Fear is easy to learn and difficult to forget; the brain is biased toward remembering the bad and forgetting the good (Davis, 2002; Vyas and Chattarji, 2004). For many adult learners, the classroom triggers memories of failure and shame that might have once driven them from school. For others, just being in the position of being evaluated triggers stress. Stressors in and out of the classroom can work to inhibit the neuroplastic functions of the brain. With this in mind, one concludes that the most effective approaches to adult learning include some way to address traumatic learning experiences from the past. Although educators are not therapists (and should not try to be), many characteristics of good mentoring echo the literature of effective counseling. Such processes can change the brain by gradually teaching it not to be fearful of the current educational environment.

However, when students examine their emotional learning state their self-identity as poor learners is often revealed and their shame triggered; they may go through a period of feeling vulnerable and angry at their teacher for "outing" them. Even if they successfully break through their negative assumptions and see that they are actually competent and capable, they may go through a period of anger and sadness about the many years they now feel they wasted. Some also experience anger at the people in their past who discouraged and shamed them. Although these issues are not directly addressed in curricula, the most effective teacher/mentors intuitively respond to these personal and internal aspects of education. When doing so, it is helpful if the teacher can identify anger that students may have displaced from the earlier

learning situation onto the current one. Through encouragement, not taking anger personally, and finding creative ways for a struggling student to approach difficult material, excellent teachers create emotionally supportive learning experiences that can rebuild the brains of their students.

From a neurobiological perspective, the role of the mentor/educator in adult brain development may be likened to the role of a primary nurturer in a child's brain development. Both offer a safe haven, emotional attunement, and a scaffold to support the learning process. This aspect of the adult educator's task is directly related to the fact that the brain is a social organ and learns best in the context of a trusting relationship. Such a relationship is the developmental "holding environment" (Kegan, 2000) in which adult learning experiences can be optimized.

Thinking and Feeling

Activation of both affective and cognitive circuits allows executive brain systems to reassociate and better regulate them. The orbitofrontal cortex, located just behind the eyes, is a major component of the executive brain system. Damage to its connections with the emotion-producing limbic structures has been shown to affect judgment, insight, and behavior (Mesulam, 1998). In both therapy and mentoring, it is essential to strengthen the orbitofrontal-limbic connections. Teachers who relay factual information and encourage critical thinking are most effective when, acting also as mentors, they help the student acknowledge and integrate intellectual challenges with emotional and physiological experiences. Such an approach helps reduce stress responses; the student is therefore able to calm down and seek appropriate resources. As a result, the neural connections of the orbitofrontal region to the limbic area may literally be expanded. Since the limbic structures are located deep down in the brain, integrating these two areas is called a top-down convergence.

The positive effects caring has on early brain development are echoed in yet another aspect of the adult's learning process. By describing what is happening and reviewing what a child has already experienced, a parent gives meaning to external events and the child's role in them. This kind of dialogue helps the child make sense of his or her own emotional and behavioral responses (Schore, 2001). In this way, the parent helps the child's brain integrate the bodily and emotional functions of the right brain hemisphere with the social and language-oriented functions of the left hemisphere. In times of fear and anxiety, the verbal centers of the left hemisphere tend to shut down, impairing the semantic and narrative aspects of learning that are central to academic success. Decreasing stress as a part of teaching balances hemispheric functioning and activates semantic and narrative processes. A teacher's role in right-left convergence mimics the original parenting dialogue. The role of interpersonal communication as a tool for development is elaborated on in the next section on narratives.

The Narrative of the Learner

The contemporary human brain embodies millions of years of evolutionary adaptation, with old structures being conserved and modified while new structures emerge, expand, and network. The proliferation of specialized networks for motor movement, emotion, thinking, and reasoning created an increasing challenge to keep the brain integrated and functioning as a whole. These interacting networks and the design compromises made in their construction create the potential for great accomplishments and potential chaos. Given that the brain's evolution is intertwined with both increasing social complexity and the emergence of language and symbolic thought, coconstruction of narratives has evolved to serve as an external organizing element of neural coherence and cohesion.

A story well told contains conflict and resolution, gesture and expression, and thought flavored with emotion. All of this is transferred from brain to brain across the social synapse. The convergence of these diverse functions within the narrative provides a nexus of neural network integration among left and right; top and bottom; and sensory, somatic, motor, affective, and cognitive processes in all parts of the brain (Siegel, 1999). Taking a broader view, narratives also serve to integrate the functioning of individuals within groups by teaching specific skills and general values, and creating common blueprints and shared understandings.

Narratives play at least two important roles in adult education: as memory tools and as expression of self-esteem. Because narratives require the participation of multiple memory networks, these stories serve as ways of enhancing memory through linked associations. For example, learning a list of words is far more difficult as a list than it is when a story is constructed containing associations to the elements to be remembered. In addition, the areas of the brain most heavily involved with list learning are also most vulnerable to the effects of aging, medication, and any sort of head trauma. The broad neural base of narratives makes it a more resilient matrix for memory.

In terms of its role in self-esteem, a learner's self-narrative becomes a blueprint for action that can turn into a self-fulfilling prophecy. Adults with traumatic learning histories have incorporated the often unthinking evaluations of parents, teachers, guidance counselors, and other students into their learning narrative. Many adult learners remember hearing comments such as, "Thank God you got the looks, because your sister got all the brains" and "You should sign up for the commercial classes because we need to fill the academic classes with college-bound kids." If such statements are unconsciously or consciously evoked by the learner in a stressful learning situation, they increase stress and decrease success. Under such circumstances, it is especially important to encourage positive and soothing counternarratives.

One strategy is to engage adults in journaling and group discussion that begins with their inner narrative about learning and moves toward

development of a new, more capable story. (See also Taylor's Chapter Nine in this volume.) Though there may be some initial anxiety and stress, the connection to others who share their experiences tends to result in the realization that "this is no more difficult than many other challenges I have faced and mastered; just relax, focus, and keep at it." Knowing one is not alone is a powerful antidote to anxiety. In addition, hearing one another's strategies and compensations may give students specific tools for success. Negative learning narratives become a self-fulfilling prophecy in that they increase stress and decrease plasticity. On the other hand, if intellectual challenges are faced with an internal story of an intention to succeed, anxiety is reduced and the neuroplastic processes required for learning are stimulated. For many learners of all ages, trust, dialogue, and healing precede genuine learning.

Wisdom

Wisdom involves integration of thoughts and feelings and blending of experience, perspective, understanding, and compassion. In these areas, adults excel. Adult learners are likely to do better in learning concepts and principles that tie to their experience and allow them to expand existing knowledge. The differences may lie in the areas of the brain that remain plastic later in life. Some adult learners learn better when asked to teach, a position more in line with their place in the life cycle. This peer-learning strategy also embeds learning of information within the social context.

On the basis of professional observation, we note that adult brains have an increasing tendency toward storytelling. This may be due not only to so many brain processes having to converge in storytelling but also to being obliged to transmit information and cultural wisdom to the next generation. It should be considered that adults might learn best through the window of own knowledge and wisdom. For the adult learner, the content of learning and the story of the self may not be separable. The classic narrative drama is a journey from fear to courage, from confusion to clarity, and from crisis to triumph. This may parallel the adult learner's reentry into the classroom. In this way, the self-vision of the learner as a master might have to precede the learning encounter. Adults may need to begin as masters by using their own experience as the basis for new learning. Recognizing and acknowledging the competence, status, and accomplishments of the adult learner activates the scaffolding for new learning. (See Johnson's Chapter Eight in this volume.) This strategy certainly appears to be in alignment with both evolution and brain development.

Current trends in neuroscience are unveiling more evidence that human brains need social interaction to promote neural plasticity. Teacher/mentors who inspire adults to learn may unconsciously embody the neuroscience of education. Their wisdom, enthusiasm, and effectiveness are due in part to an innate grasp of what it takes to support brain development

in adults. In any case, understanding the brain's processes further enhances what they may intuitively already know.

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