

Fear in Love: Attachment, Abuse, and the Developing Brain

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Editor's note: Why do abused children attach and remain attached to abusive parents? In this article, Dr. Regina Sullivan explains how her research with rat pups has led to greater understanding of the infant brain, and how negative early experiences can cause long-term genetic, brain, behavioral, and hormonal changes that can affect not only the abuse victim but also the victim's descendants.

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Many parents have absolute faith that, with the right kind of stimulation, they can give their child an educational advantage. Conscientious mothers play Mozart to the baby in the womb, take their toddlers to Mommy and Me dance classes, and work their way through preschool applications as daunting as those for medical school. Yet even with the wide range of advantages available for infants today, many people are still surprised when I tell them that the way they treat their children will actually change the structure and circuitry of the child's brain.

Though prenatal Mozart has not been proven to boost IQ, the day-to-day stimulations of a nurturing, interesting, stable home life most certainly can sculpt the circuitry of the brain. Reading, singing, showing colorful pictures to a child—and especially talking and cuddling—help shape the child's development in a very real, neurobiological way. In the parts of the brain that are stimulated, individual neurons flourish like tiny trees, sprouting more of the branches, called dendrites, that allow communication between cells. Neural circuits form, followed by complex networks, allowing the child to flourish in the outside-world social networks of family, friends, school, and community. The child's genes provide the framework, but early-life experiences will determine how those genes contribute to the emotional, intellectual, and social life of the child—and to the adult that the child will become.

Unfortunately, the same process plays out when the child's early experiences are not happy ones. The brains of children who suffer neglect or abuse—about 10 out of every 1,000 children in the United States in 2008¹—also develop in a way that reflects the child's experiences. And the effects of early abuse can be notoriously difficult to detect. Contrary to commonly held beliefs, it is difficult to identify an abused child unless there are obvious signs, such as bruises or injuries. The child's behavior usually provides few clues—in fact, when social workers, doctors, or police officers attempt to rescue a child from an abusive situation, the child will often lie to protect the parents.

It usually takes a skilled therapist with specific diagnostic tools to uncover definite signs of abuse. One method is the Strange Situation Test, in which a caregiver brings a child into a room and then leaves, after which a stranger comes in and attempts to engage the child. Only after repeated rounds of these stressful events—and after the final stage of this test when the child is reunited with his or her mother—will the child finally begin to show signs of “disorganized attachment,” simultaneously showing a need for and a fear of the caregiver.

Yet by adolescence, some 80 percent of abused children will be diagnosed with major psychiatric illness. Imaging studies of abuse survivors often show that brain areas controlling emotion and cognition are abnormal, both anatomically (they are generally smaller) and functionally.

These facts illustrate two of the biggest obstacles to successfully treating, and preventing, child abuse. The ability to bond with a caregiver is such a strong biological imperative that once a bond is formed—even with an abuser—it is difficult to break. And the devastation resulting from abuse often will not become fully apparent until the child is well into adolescence. To help these children overcome their attachment to the abuser and avoid psychiatric disorders later in life, it’s important to understand the mechanisms through which abuse leaves its mark on the brain. Since the 1950s, researchers have raised many interesting questions and are only now beginning to provide some of the answers.

The Beginnings of Attachment

Within moments of birth, a human baby enters into a state of quiet alertness that lasts for hours. The newborn rests quietly with eyes open, orienting to the faces, voices, and scents of humans. Some hardwiring in the baby’s brain makes this bonding possible: babies are born with a preference for the high-frequency sounds of the human voice and for the general shape of the

human face. But the infant also needs to learn about the caregiver. This learning begins before birth as the baby becomes familiar with the mother's voice and odors. The newborn continues rapidly to learn more voices and smells, responding more intensely.

Throughout the animal kingdom, once a newborn knows its mother it will do its best to remain with her. Animals that are mobile soon after birth, like horses or goslings, follow their mothers everywhere. Newborns not yet ambulatory, including humans, will cry for their caregiver.

It seems inconceivable that any child, puppy, baby monkey, or chick would develop an enduring bond with an abusive caregiver. Puzzling out the explanation requires a shift in the ways brain and behavior have been traditionally viewed.

For much of the twentieth century, psychology followed a behaviorist model: An animal will repeat a behavior that triggers a reward, and will not repeat a behavior that's punished. Following this logic, a baby would do its best to avoid an abusive caregiver, or at least show signs of distress in that person's presence. But the research of Harry Harlow at the University of Wisconsin, Madison, beginning in the 1960s, showed just the opposite. Harlow raised infant monkeys with a "surrogate" mother (a wire tube wrapped in cloth with a plastic monkey head on top). In one experiment, baby monkeys clinging to the surrogate would hold on even when subjected to an unpleasant puff of air. Similar results show up in studies of other species, including chicks and rats—and in many heart-wrenching headlines of abused children, battered wives, and kidnapping victims who stand by their tormentors.

Scientists suspecting a brain-based explanation were hampered not only by the behavioral hypothesis but also by prevailing views of brain development. Throughout much of the 20th century, researchers understandably assumed that the brain became more sophisticated with age—that the young brain was, in fact, immature. Recently, however, our view has shifted. The

infant brain is actually perfectly developed to accomplish the tasks appropriate to the survival needs of infancy. Some of the unique functions of the infant brain help to explain why a child will bond with whatever caregiver is available.

A Mother's Presence is a Biochemical Off Switch for Fear

Because of ethical concerns, it's difficult to scan the brains of most children; it is certainly unethical to upset an abused child even further by presenting traumatic events during a brain scan. Scanning also presents logistical problems in children, since the child needs to remain perfectly still during the scan. It is possible, however, to study normal and abusive attachment in rats. Though rats learn about their mothers entirely through smell—seeing and hearing do not emerge until the rat pup is around two weeks old—rats are similar to children in that they have a biologically predetermined attachment system in the brain but must learn to identify and remember the caregiver.

For this reason, we began to use “attachment learning” in rats to question what it is about an infant's brain that supports attachment, even when the caregiver is abusive. An early clue was the involvement of the brain chemical norepinephrine. The neurotransmitter is released in massive amounts at birth and during bonding with the mother. It is also released when a young animal is in pain.

This dual role for norepinephrine set us on the path to explore the fundamental, and puzzling, question of why a child cannot learn to break the attachment to an abusive caregiver. After all, when humans and all other mammals experience pain, they learn to avoid anything that warns of the pain so that they can prevent it next time. So in an abusive relationship, why doesn't the pain activate the brain's fear and avoidance circuits?

Simply and amazingly, the brain area responsible for fear and avoidance learning is not turned on by pain in pups not old enough to leave the nest. Even more amazingly, in older pups that live in the nest but also explore outside the nest, this brain area shuts off only when the pups are with the mother.

We worked first with young rats still nesting with their mothers, when they are blind and deaf and must depend upon the mother's odor for attachment. The maternal odor is so important that without it, pups die. First, we paired a novel odor with a painful experience, such as a mother rat handling pups roughly, a tail pinch, or a slightly painful electric shock. That odor became a new maternal odor that controlled the pups' approach to the mother and enhanced social behavior and feeding with the mother. Older pups that could leave the nest reacted very differently: they learned to avoid an odor paired with pain. But to our surprise, if the mother was with these older pups during the learning, they were attracted to the pain-associated odor, and examination revealed no activation of stress networks in the brain. That is, the mother's presence can act as a biochemical switch, determining whether rat pups will develop an aversion or an attraction to a mildly painful event.^{2,3}

My colleagues and I were perplexed by these results. These pups should have learned to avoid the odor. It took time for us to change our thinking and view the infant brain as a brain designed for infant survival, rather than as an incomplete adult brain. We were completely surprised by the paradoxical result that pain would lead an infant to approach, even seek, a newly learned odor. We were even more astonished by the ability of maternal presence to reinstate this paradoxical learning in older pups. Once these initial results were uncovered, we wanted to determine the mechanisms involved.

The key to the young rat pups' behavior is an almond-shaped structure known as the amygdala, a part of the brain involved in emotionally charged memories—especially fearful

ones. The presence of the mother during a painful event is enough to suppress activity in the amygdala of a rat pup. The mechanism proved to be surprisingly simple: pups still living in the nest, or older pups in the mother's presence, did not release the stress hormone corticosterone. The infant amygdala is uniquely dependent upon increases in corticosterone to learn and express fear. In a later study, we showed that the neurotransmitter dopamine is also released when the rat is learning to avoid the odor. Though dopamine is often considered a "reward" chemical, when increased in the amygdala it helps to form fear-related memories. In this study, young rats still in the mother's nest showed a large decrease in dopamine in the amygdala, indicating a mechanism to further block pups from learning to fear.⁴

The benefits of this maternal off switch seem obvious. Nearness to the mother offers comfort and courage in what might otherwise be a frightening situation, serving to strengthen the bond between mother and infant, and to remind an older child where its haven is in times of danger. This phenomenon is known as "social buffering," and it continues throughout life. When a child gets an injection, the presence of a parent can help the child cope with the pain. Later on, when someone we care about is there to comfort us in a stressful situation, our stress hormones and fear are greatly reduced.

The switch is flipped, however, when the intrepid older rat pup is out exploring. Then, the threatening event sparks the fear response, propelling the youngster away from danger and, preferably, back into the nest while searing an indelible memory into the brain.

But when the parent and the nest are themselves sources of danger, the suppression of fear circuits in the amygdala unfortunately still works. The fear, avoidance, and even memories associated with pain are extinguished—explaining why an abused child, even while trying to escape pain, will later seek contact with the abuser.

Neurons Build Walls Around Memories

Under normal circumstances, the ability to remember danger is so vital to survival that memories based on fear cannot be erased. They can be overwritten through “extinction,” an active-learning process in which a new memory supplants the older one (like teaching a rat that a shock will no longer follow the sound that used to precede it). But extinction is shaky and impermanent, and the underlying fear can re-emerge at any time.

Key neurons in the brain build structures that reinforce fear-based memories. These “perineuronal nets” are made of cartilage-like tissue known as proteoglycans. Like miniature chain-link fences, they are thought to protect important memories by blocking the re-modeling, or plasticity, that might otherwise dismantle the memory in favor of new information.

Once again, the formation of these barriers is age-dependent. Andreas Luthi of the Friedrich Miescher Institute for Biomedical Research in Switzerland and Cyril Herry of INSERM in France showed that in adult mice whose fear of a shock has been reprogrammed through extinction, treatment with an enzyme that degrades the “nets” will bring the memory back in full force; the mice showed the same freezing behavior in response to a warning odor that they did before extinction training took place.⁵ But younger pups, less than three weeks old, can lose a fearful memory completely. Like our work with norepinephrine circuits, this research also illustrates a concrete mechanism that prevents young children from forming memories based on fear—even when it might be in their best interest to do so.

Loving Care Sets Brain Development on the Right Course

The animal research explains an infant’s biological drive to stay close to a source of food and safety. But we know that even when basic needs—food, clothing, shelter, medical care—are adequately met, children are still devastated by the loss of a parent. Children in orphanages

whose basic needs are met (who receive “perfunctory care,” in medical parlance) often fail to grow and do not reach developmental milestones at a normal pace. Later in life, these children are more likely to have profound mental problems, including difficulty maintaining social relationships. The early work of Harlow and colleagues attests to the importance of “attachment figures.” In an experiment well known to every first-year psychology student, a baby monkey will choose a warm, soft, cuddly artificial mother with no food over a wire one with a bottle attached.

More recently, the importance of a loving caregiver early in life has been underlined by studies of teenage Romanian orphans left by impoverished parents to be raised in overcrowded, understaffed, improperly run state institutions. Even when adopted and cared for by loving families, some of these children remain detached and have emotional and cognitive impairment. Some encouraging findings, however, show a group of resilient children who overcame these early-life disadvantages; they were adopted before age two and placed in loving families that gave enormous time and energy to their rescue.

What specifically does a loving caregiver provide, without which even a healthy, well-fed child will languish? Once again, animal research offers some clues. Rats are devoted mothers and spend copious time licking, snuggling, and crouching over their young. Myron Hofer of Columbia University has shown that the intense sensory stimulation a rat pup receives regulates the behavioral, physiological, and neural development of the brain.⁶ This line of research has shown that when rat pups are separated from their mother, mimicking her actions by stroking can increase levels of growth hormones in the infants’ brains; extra warmth (normally provided by the mother’s body heat) increases levels of norepinephrine; and giving the pups a whiff of their mother’s scent ramps up their level of activity.

Once basic needs of the infant are met through social interactions, presenting an environment that is interesting but age appropriate appears to optimize behavioral and brain development. A recent study in rats by Akaysha Tang and Bruce McEwen showed that infant rats that experienced just three minutes of novelty each day exhibited enhanced learning and more controlled stress response in adulthood.⁷

Abuse Alters Gene Activity

Traumatic experiences such as abuse can work their way into a child's genes. This fact may come as a surprise, since most of us think of genes as something we are born with. Of course, the genetic material we receive from our parents is important, and lays the foundation for who we are and what we become. But how our parents treat us as we grow can greatly influence the way the genetic material is "read" and used. Think of our genetic material as a vast library of information. The way this information is accessed, and what ends up being done with it, depend in great part on our early-life experiences.

The influence of outside-world factors on our genes is known as epigenetics. An epigenetic change occurs during the biochemical process of turning a gene's code into whatever protein that gene codes for—in scientific parlance, the process of gene expression. The concept of epigenetics helps explain why so many effects of child abuse do not become apparent until adolescence or adulthood. It may also hint at why abused children often grow into abusers themselves.

It may seem obvious that a mother's handling of her child will influence the way that child treats her own children. The transmission of this trait from mother to daughter and beyond may result from epigenetic alterations to genes involving estrogen sensitivity, according to research from Frances Champagne of Columbia University and Michael Meaney of McGill

University. These researchers showed that the amount of care a newborn female rat receives in the form of licking and grooming will determine how much licking and grooming she will do for her own pups—and they for theirs.⁸ In 2006 this team found that a mother’s licking and grooming activity can modify the expression of a gene involved in several aspects of reproduction, resulting in differing levels of a particular estrogen receptor in adulthood. Consequently, a rat’s sensitivity to her own estrogen levels can change, leading to changes in the way a mother handles her pups for at least two generations.

Animal studies show that epigenetic changes also occur in abusive situations. Tania Roth, David Sweat, and colleagues at the University of Alabama, Birmingham, found that when rat pups were raised by stressed mothers who behaved abusively, the pups—and their pups—showed changes in the gene producing a substance known as brain-derived neurotrophic factor (BDNF).⁹ The job of growth factors is to nourish and protect brain cells; BDNF in particular helps to stimulate the birth of new neurons (a process known as neurogenesis). The gene alterations in the abused pups showed up in the hippocampus and the prefrontal cortex. Since BDNF and neurogenesis in the hippocampus help to support learning and memory, and both help ward off stress and depression, this animal finding points to one route through which abused children can suffer from emotional and cognitive problems throughout life.

Some recent research hints at epigenetic changes in people who were abused as children. In 2009, Meaney and colleagues examined brain tissue obtained postmortem from a group of suicide victims, some of whom had been abused early in life and some of whom had not. The brains of the abuse victims showed several differences. In the hippocampus, receptors for the stress hormones known as glucocorticoids were fewer in number, and the genes encoding the receptors had alterations in the “promoter” region, where the process of gene expression begins. In a healthy brain, glucocorticoid receptors are plentiful in the hippocampus, where they play

several roles in memory, emotion, and the stress response—including helping to consolidate fear-related memories. Some conditions, like major depression and post-traumatic stress disorder, involve a loss of the neurons containing these receptors; both conditions can involve memory loss as well. This pattern of epigenetic change did not show up in the brains of suicide victims who were not abused, or in control subjects who had died of natural causes.¹⁰ The differences imply that the abuse caused the changes in the hippocampus—not that people who commit suicide have an underlying brain anomaly making them more likely to take their lives.

Conclusions

Technological advances, coupled with our new understanding of the uniqueness of the developing brain, have direct implications for child rearing. Assuming that basic nutritional and health needs are met, what do we need to do to optimize brain development? Not Mozart or that developmentally designed mobile. The developing brain overwhelmingly requires a loving, consistent, and patient caregiver who socializes with the infant, punctuated with age appropriate novelty and learning. This organizes brain circuits and gene expression for cognition and emotion to yield a cognitively and emotionally well-balanced child and adult.

What is detrimental to brain development? Neglect or emotional or physical abuse that produces either heightened or prolonged activation of the stress system results in later-life difficulties. While we are less sure how these early-life experiences change the brain, we do know that the brain responds by changing its structure, gene expression, and function. How do we help a traumatized child recover? No magic pill has been identified. Instead, heightened caregiving and therapy involving social behavior are key. In other words, we are social creatures, and our social interactions in early life design the brain to greatly influence the person we become.

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