BRAIN EVOLUTION AND HUMAN COGNITION: THE ACCIDENTAL MIND*

DAVID J. LINDEN**

I'd like to speak with you about brain evolution. You are probably thinking, "Why should I care about brain evolution? Sure, I might care about brain function and human cognition as it impacts legal and societal thought. But why should I care about *how* the brain got that way? I just care about the way it is now." I hope to convince you that you can only care about the way it is now, and the most human and central aspects of the way it is now through an evolutionary story.

~

It's 1975 and we're in the laboratory of Dr. Larry Weiskrantz at the University of Oxford. Larry is studying a population of patients who are blind, not as a result of direct damage to their eyes, but because, at some point in life, they had a blow or a stroke that impacted the visual cortex, the region at the back of the brain that processes visual information. These folks are utterly blind in their daily life. They report no perceptual abilities.

Weiskrantz did what was, on the face of it, a useless experiment. He put a letter in the hands of these folks, and in front of them was a mail slot. The mail slot was oriented either horizontally or vertically, and he asked them to insert the letters into the slot. The subjects replied, "What are you talking about? We are completely blind; what a waste of time; I do not have any idea; I would just be utterly guessing." He said, "Just go with your gut and we will see what happens." He ran the experiment with a number of subjects, and not all of them, but a very large fraction of them were able to orient the

* This Article is a lightly edited transcript of the author's keynote address delivered at the Willamette Law Review's Law of the Body Symposium, held at the Willamette University College of Law on March 7, 2008. The transcript has been edited for clarity and grammar by the Willamette Law Review.

** Professor of Neuroscience, the Johns Hopkins University School of Medicine. D.J. L is supported by the National Institute of Mental Health and the Develbiss Fund.

letter into the slot correctly. Not every time, but a much larger fraction of time than chance; a very statistically significant increase.

So, to explain this result, do we have to invoke ESP or fairies or

design of the lizard brain. Rather, you take the lizard brain and you add some stuff on top. In addition to this midbrain, now you elaborate what's called a limbic system, some emotional centers, some memory centers, and you add a little bit of what we call neocortex, which is the rind that's on the top of the brain. If you want to build a monkey, then you expand the neocortex enormously. If you want to build a human, then you expand the neocortex more so, particularly the most frontal parts of the neocortex.

As a consequence of the brain's ice-cream-cone-like design, it's very inefficient. What this means, for example, is that in our brains we have two auditory systems: an evolutionarily ancient one that we share with lizards, and an evolutionarily modern one that we share with mice and monkeys. We also have two visual systems; the information from our eyes bifurcates, and some of it goes to our ancient visual system, and some of it to our modern visual system.

So, to return to Larry Weiskrantz's lab, what happened to our cortically blind people who were putting their letter in the slot properly? The answer is that they had damage only to their modern visual system. Their ancient midbrain visual system was intact, but information flowing to this system is not something of which we are consciously aware, even though it can help guide our actions. As a consequence, the conscious mind of those cortically blind folks reported that they were guessing randomly, but the information in their intact ancient visual system was available—subconsciously—to help them guide their decisions. This is an example of a neurological result that can only be understood in terms of considering the evolution of the brain.

~

ear have to go to other places in the brain to process auditory information." The general wiring diagram is encoded genetically, but at the finest level, the wiring diagram is driven by sensory experience.

Brains are not all neatly wired up at birth. In short, they are very crudely wired up, and you need experience to sort out the fine details of wiring. Interestingly, that experience starts in the womb. You need experience starting in late fetal life and continuing up until about age five to wire up the brain properly. That means that your brain cells have to be malleable. They have to have the ability to take sensory information, and based upon the patterns of that sensory information, produce lasting changes to the wiring diagram and the efficiency of communication between neurons and the brain. Once you have that ability to wire up the brain guided by experience, what have you achieved? You have the substrate of memory. You have the ability to become an individual. You have the ability for your experiences to mold your brain and write those memories that make you unique.

However, we have crummy neurons as processors. We have to build this big, fat, horrifically large interconnected brain to be cognitively clever with those awkward, inefficient processors. Then, we cannot specify the wiring diagram of this big, massively interconnected brain in the DNA, so the only way we can build it is have the wiring be partially experience-driven. Then, when we have the ability of experience to modify our neural circuits, this gives us memory and the individuality that it confers. A centrally human aspect of our lives comes from the fact that evolution is a kludgy, tinkering process. Our memories and our individuality are not the latest perfectly engineered feature of an impeccably designed brain. They are what have emerged from an ad hoc, work-around solution to try to design a clever brain with lousy jellyfish neurons, almost Rube-Goldberg-esque in its so-called complexity.

~

What about love? I hope to prove to you that our human mating system also derives from the fact that neurons are lousy processors. Our adult human brains are about twelve hundred cubic centimeters in volume. When we are born, our brains are about four hundred cubic centimeters, about the same size as an adult chimp. As women know, it's not trivial for the brain and skull of the newborn to pass through the birth canal. Death during childbirth is almost a uniquely human phenomenon. None of our close primate relatives die in childbirth. We are already maximizing the volume that the brain can be at birth.

Then, we have the situation where humans have, by far, the longest childhood of any animal. There is no other animal where a five-year-old cannot make its way in the world independently. The human brain is developing at a furious pace from birth to age five, and then at a much slower rate from age five to about age twenty. How does this play out in our love lives? For this, I refer to a little segment of my book:[1]

> Humans are truly the all-time twisted sex deviants of the mammalian world. I'm not saying this because some of us get turned on by the sight of automobile exhaust systems, the smell of unwashed feet, or the idea of traffic cops in bondage. After all, other species are at a disadvantage in expressing their kinks by not having reliable access to the Internet. Rather, I mean that the more prosaic aspects of sexual activity in humans are far outside the mainstream of behavior for most of our closest animal relatives.
>
> The spectrum of human amorous and sexual behavior is wide and deeply influenced by culture (and I will consider these issues shortly), but let's first talk about the generic presumed norm: regular, old-fashioned monogamous heterosexual practice. Then we can see how it compares with the practices of most other mammals. The simplified human story, stripped of all the romance, is something like this. Once upon a time, a man and woman met and felt mutual attraction that they codified in a ceremony (marriage). They liked privacy for their sexual acts and they declined opportunities for sex with others. They had sex, including intercourse, many times, in most phases of the woman's ovulatory cycle, until she became pregnant. Once it was known that the woman was pregnant, they continued to have sexual intercourse for some time thereafter. After the baby was born, the man helped the woman to provide resources and sometimes care for the child (and for the other children that followed). The woman and man continued their monogamous relationship and remained sexually active well beyond the woman's childbearing years, as marked by her menopause.
>
> Now let's hear another perspective. The comedian Margaret Cho uses the line "Monogamy is sooo weird . . . like . . . when you know their name and stuff?" This brings down the house in a comedy club, but the idea is actually the dominant one in the nonhuman world: more than 95 percent of mammalian species do not form lasting pair bonds,

---

1. Reprinted by permission of the publisher from THE ACCIDENTAL MIND: HOW BRAIN

E

offspring? Indeed, the females of many species, including many mammalian species, do exactly that. The crucial difference is that although a female orangutan, for example, easily rears her off spring alone, human females don't have it so easy. Most other animals are able to find their own food immediately after weaning, but human children do not achieve this level of independence for many more years. As a consequence, the reproductive success of a female human is much greater if she can establish a l brain—it just wouldn't fit. As it is, death during childbirth is a significant human phenomenon, particularly in traditional societies, whereas it is almost unknown among our closest primate relatives.

As a consequence of all this, human females are uniquely dependent on male support to raise their offspring. They secure their reproductive success by having concealed ovulation, which compels males to adopt a strategy of mating with one female repeatedly throughout her cycle. This monogamous, mostly recreational sex has two effects: it gives a high probability of accurately knowi scream "*Yeeow that hurts!*" If you ask them where it hurts, they will say they do not know, it just does.

In order to have this experience of pain that we think is irreducible, we need one neural center that is processing the emotional aspect and another that is processing the sensory aspect, and they are anatomically distinct. We may say we experience emotional pain, but is this merely metaphoric language? Is the pain of being excluded from some social interaction, for example, really basically the same as the pain from my finger hurting? What is amazing, though, is that when you do brain scanning experiments like those I just discussed, social pain and physical pain have highly overlapping patterns of brain activation. Emotional pain and physical pain share neural substrates in the brain.

What about pleasure? What about, say, orgasm? Orgasm is something that we think of as intrinsically pleasurable. However, just like pain, you can distinguish in the brain the pure sensory/discriminative component of orgasm from the emotional component of orgasm. For example, if I were to put an electrode into a part of your brain called the medial septum and stimulate it, I could produce an orgasm in you that would be more like "whoops!" than like the kind of orgasm you normally would experience. It would be a purely sensory orgasm with no emotional component. There are people who have orgasms that are triggered by seizures, and sometimes those seizures can invade both the emotional center and the sensory center and produce an orgasm that is like a normal behavioral one. Sometimes, they will only affect the sensory center, and they will produce an orgasm that is devoid of the affective component.

We are so used to sensation and emotion being blended in our experience, that it can seem very cognitively dissonant when they are separated. For example, there is a neurological phenomenon called Capgras syndrome, named after the French doctor who originally described it. This is a very odd disease. Afflicted people are convinced that their close relatives, or sometimes even their pets, have been kidnapped and replaced with very accurate replicas. You might at first think that these people are mentally ill or hallucinating, but they are not. They are otherwise psychiatrically normal. Here is what is weird: you have someone who is convinced their parents have been replaced by exact replicates when they see them; however, when they get their parents on the phone, they will act as if they are speaking to their real parents. The problem is solely with visual information. What happens in the brains of people with Capgras syndrome? The visual information that normally drives emotional centers that would be activated by familiar people or animals is not occurring in Capgras syndrome patients. These people are seeing their parents, but they are not feeling emotionally what they would expect to feel. As a consequence, they create an explanation that their loved is an extremely common phenomenon. Amnesiacs believe their own confabulations.

When we dream, what is going on? We have our experiences during the day and we need to consolidate all of this sensory input, to write certain aspects of those experiences into memory. That is best done at night in the absence of competing sensory information. If you take someone who is dreaming, and you put them in a brain scanner, and you ask what parts of the brain are active, someone may be having a highly visual dream, but their main visual cortex that is active in waking vision is shut down. Their visual memory centers however, are extremely active. The regions in the frontal cortex that are normally active with reasoning and logical thought are shut down. That is what allows dreams to be so bizarre. The left cortical regions that are associated with this interpreter function and are stitching disparate things together to make a story, they are very active. So when you dream, why are your dreams not just a flash in your memory that is being consolidated and a flash of that? Why do dreams, particularly in the REM stage of sleep, have to be in the form of stories? The reason is, because your brain cannot help it. It cannot help but make a story out of those disparate scraps of information.

Now, I would like to bring up religion. Religion is a cross-cultural universal. There is no culture that has ever been found that does not have religious thought. If you ask people why all cultures have religion, they come up with explanations like, "Well, religion provides answers to difficult questions," or, "it enforces a societal moral code," or, "it gives promise of an afterlife that is somehow comforting." These explanations are true in some cases, but actually, all of those explanations fail the broad cross-cultural test. There are religions that do not promise an afterlife, and there are religions that do not particularly enforce a moral code, and there are religions that do not have an origin story at all. If you were to ask a question about the universality of religious thought, one way to approach it is through consideration of common brain functions that we share across cultures. It is the narrative creation function that we have that allows for this, and this narrative creation gives rise not just to religious thought, but also to scientific thought.

scientific hypothesis, my story has to be falsifiable." For example, we have a story about human evolution. It is a hypothesis. If tomorrow you dig up a hominid skeleton that comes from the time of the dinosaurs, then my evolutionary hypothesis fails and has to be rejected. In religion, we similarly creative a narrative from incomplete fragments of information and call it a sacred text. It is not subject to falsifying experiment or observation and in this way is different from a scientific hypothesis. But, the initial act of narrative creation is shared with scientific hypotheses.

John Brockman, who is the editor of an online journal called EDGE, surveyed a group of scientists and asked, "What do you believe, but cannot prove?" You might think that a significant fraction of scientists would have said, "I'm a hardheaded rational atheist, there is nothing that I believe I cannot prove," but in truth, every single person asked had an answer. Some of the ideas they had were scientific hypotheses. Some of the ideas were narratives that are not falsifiable, and therefore constitute faith. Religion and science in our culture are often put at opposition, but in truth, they are two branches of the same cognitive stream. Both derived from an always-on brain center for narrative creation. The things that we hold most