Chapter 1
The Neurochemistry of Science Bias

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Dr. Ignaz Semmelweis was shunned by the nineteenth-century medical establishment for telling doctors to wash their hands. His belief in invisible disease-causing agents was ridiculed by his peers. We hope this could not happen today because the scientific method keeps us focused on replicable data. But Semmelweis's critics likewise perceived themselves as defenders of evidence-based science (Nuland, 2003). They invoked the greater good in their dismissal of his findings. How is it possible for people intent on objectivity to dismiss essential information?

Two familiar answers are *confirmation bias* and *paradigm shift,* but neither explains it entirely. Confirmation bias is incomplete because it typically omits the investigator's own bias. For example, Semmelweis's critics could accuse him of confirmation bias without acknowledging their own biases. Paradigm shift is incomplete because it does not explain how a brain actively rejects information without conscious awareness.

Brain chemistry offers a new way to understand information-processing biases. Brain chemicals cause positive feelings about one chunk of information and negative feelings about another (Damasio, 1994). Feelings are presumed irrelevant to empirical analysis, but they are highly relevant to the brain's constant extraction of meaning from an overload of inputs. The neurochemicals of emotion are easily overlooked because they do not report themselves to the verbal brain in words. Their absence from our verbal inner dialog leads to the presumption that we are not influenced by them. The impact of emotion on empirical inferences is often more observable in others. The ability to recognize our own neurochemical responses to information is a valuable scientific tool. This paper explains these responses in animals, which illuminate their nonverbal motivating power in humans. Some examples of this motivating power are drawn from modern social science.

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D. M. Allen, J. W. Howell (eds.), *Groupthink in Science*,
https://doi.org/10.1007/978-3-030-36822-7_1

Nature's Operating System

The reward chemicals and threat chemicals in humans are inherited from earlier mammals. These chemicals evolved to promote survival, not to make a person feel good all the time. Each chemical has a specific survival job that is observable in animals. Here is a simple introduction to the natural function of three reward chemicals (dopamine, oxytocin, and serotonin) and the threat chemical, cortisol. (This discussion will be somewhat oversimplified for heuristic purposes, because the various neurotransmitters often regulate one another in various complex feedback loops, making the overall picture somewhat more complicated.)

The operating system we share with animals motivates survival behavior by releasing a chemical that feels good when it sees something good for its survival, and a chemical that feels bad when it sees something bad for its survival. The human brain differs from other animals of course. The differences get a lot of attention, particularly our large cortex, so it is useful to review the similarities. Our neurochemicals are controlled by brain structures common to all mammals, including the amygdala, hippocampus, hypothalamus, and pituitary. This core operating system does not process language, yet it has allowed mammals to make complex survival decisions for 200 million years. It works by tagging inputs as reward or pain, which motivates approach or avoidance. A pleasant-feeling chemical motivates an organism to go toward a reward, while an unpleasant-feeling chemical motivates withdrawal from potential threats (Ledoux, 1998).

Humans define survival with the aid of a large cortical capacity to store, retrieve, and match patterns in information inputs. But we make these patterns meaningful by responding to them with a chemical that says, “this is good for me” or “this is bad for me” (Gigerenzer, 2008).

Natural selection built a brain that defines survival in a quirky way. It cares about the survival of its genes, and it relies on neural pathways built in youth. Anything relevant to the survival of your genes triggers a big neurochemical response. Neurons connect when the chemicals flow, so old rewards and threats build the neural pathways that alert us to new potential rewards and threats. This happens throughout life, but the pathways connected in youth become myelinated, which allows electricity to flow through them almost effortlessly. This is why old responses feel reliable, even when they conflict with new knowledge. And it is why our positive and negative neurochemistry is so poorly explained by our conscious verbal thoughts about survival (Kahneman, 2013).

The electricity in the brain flows like water in a storm, finding the paths of least resistance. The cortex can define rewards and pain in complex ways with its huge reserve of neurons, but it can only process a limited amount of new information at a time. Thus, we are heavily influenced by the pathways we already have. We are not consciously aware of these pathways, so we tend to overlook their influence over our thought process and presume that our declarative reasoning is the whole story (Ledoux, 2002).

No one consciously sifts new inputs through an old filter, but this is how the brain is equipped to make sense of its information environment. We have 10 times more neurons going from the visual cortex to the eyes than we have in the other direction (Pinker, 1997). This means we are 10 times more prepared to tell our eyes what to look for than we are to process whatever happens to come along. Our ancestors survived because they could prompt their senses to find information relevant to their survival. Neurochemicals are central to the prompting mechanism. The mammalian brain evolved to honor its neurochemical signals as if its life depended on it, not to casually disregard them. Here is a closer look at some chemicals of reward (dopamine, oxytocin, and serotonin) and pain (cortisol) and their role in our inferences about the empirical world.

Dopamine

The brain releases dopamine when a reward is at hand. A person may think they are indifferent to rewards because they do not respond to rewards that others value. But each brain scans the world with pathways built from its own past dopamine experiences. When it sees an opportunity to meet a need, dopamine produces a great feeling. This motivates us to do things that trigger it, and to lose interest in things that do not trigger it (Schultz, 1998).

Dopamine releases the energy that propels a body toward rewards. We humans experience this as excitement, but the physical sensation makes more sense when viewed from an animal perspective. A lion cannot get excited about every gazelle that crosses its path because its energy would be used up before it found something it could actually catch. A lion survives by scanning the world for a reward it realistically expects based on past experience. When a lion sees a gazelle within its reach, dopamine! That releases the energy needed for the hunt. Most chases fail, so a lion's brain constantly reevaluates its course of action. If it succeeds at closing in on the gazelle, dopamine surges, which tells the body to release the reserve tank of energy.

We are designed to survive by reserving our energy for good prospects, and dopamine guides these decisions. Our hunter-gatherer ancestors scanned for evidence of food before investing energy in one path or another. A modern scientist meets needs in different ways, but the same operating system is at work.The good feeling of dopamine motivates us to approach rewards, as defined by the neural pathways we have.

Dopamine is metabolized in a few minutes, alas, and you have to do more to get more. This is why we keep scanning the world for new opportunities to meet our needs. The brain habituates quickly to old rewards, so it takes new reward cues to turn on the dopamine (Schultz, 2015). When berries are in season, they stop triggering dopamine in a short time because they no longer meet a need. Then, protein opportunities turn on the good feeling, until nuts are in season. Dopamine focuses our attention on unmet needs by making it feel good. Today's scientists seek new discoveries because they stimulate dopamine.

Social rewards are as relevant to a mammal's survival as material rewards. Once physical needs are met, social needs get the brain's attention. The brain makes predictions about which behaviors will bring social rewards in the same way that it predicts which path is likely to lead to a berry tree: by relying on the neural pathways built by past experience (Cheney & Seyfarth, 2008). One may believe they are indifferent to social rewards, but anything that brought social rewards in your past sends electricity to your dopamine, which motivates an approach.

The brain defines social rewards in ways that are not obvious to one's verbal inner dialog. Mammals are born helpless and vulnerable, and thus need reliable attachments to survive. They evolved a survival strategy based on safety in numbers. To the mammal brain, isolation is a survival threat and social alliances are a valuable reward. Alliances with kin are especially rewarding to the brain built by natural selection (Wilson, 1975). (More on this in the "Oxytocin" section below.)

Our mirror neurons activate when we see others get rewards (Iacoboni, 2009). This wires us to turn on the dopamine in ways we see work for others. Our brain promotes survival by observing the patterns of rewards and pain around us, which helps us create a better hunting tool or a better grant proposal.

Oxytocin

Social alliances promote survival, so natural selection built a brain that rewards you with a good feeling when you build social alliances. Oxytocin causes the feeling that humans call "trust" (Zak, 2013). Oxytocin is not meant to flow all the time because trusting every critter around you does not promote survival. The mammal brain evolved to make careful decisions about when to trust and when to withhold trust. It releases the good feeling of oxytocin when there is evidence of social support.

Safety in numbers is a mammalian innovation. Reptiles avoid their colleagues except during the act of mating, when they release an oxytocin-equivalent. Reptiles produce thousands of offspring and lose most of them to predators. Mammals can only produce a small number of offspring, so they must guard each one constantly in order to keep their genes alive. Oxytocin makes it feel good. It causes attachment in mother and child, and over time it builds pathways that transfer this attachment to a larger group.

A mammalian herd or pack or troop is an extended warning system. It allows each individual to relax a bit as the burden of vigilance is spread across many eyes and ears. This only works if you run when your herd mates run. Mammals who insisted on seeing a predator for themselves would have poor survival prospects. We are descended from individuals who trusted their herd mates. We humans are alert to the risks of herd behavior, of course. But when we distance ourselves from our social alliances, our oxytocin dips and we start to feel unsafe. Even predators feel unsafe without a pack: a lone lion's meal gets stolen by hyenas and a lone wolf cannot feed its children. We have inherited a brain that constantly monitors its social support.

But life with a pack is not all warm and fuzzy. Trust is hard to sustain in proximity to other brains focused on their own survival. And the social alliance that protects you today can embroil you in conflict tomorrow. Yet, mammals tend to stick to the group because the potential pain of external threats exceeds the potential pain of internal threats. Common enemies cement social bonds, and oxytocin makes it feel good. Each brain turns it on with the pathways of its unique individual oxytocin past. Each scientist recognizes the rewards of social alliances and potential threats to those alliances, whether they put it into words or not.

Serotonin

An uncomfortable fact of life is that stronger mammals tend to dominate weaker group-mates when food and mating opportunity are at stake. Violence is avoided because the brain anticipates pain and retreats when it sees itself in the weaker position. Yet, an organism must assert itself some of the time for its genes to survive. Serotonin makes it feel good. Serotonin is not aggression but the nice calm sense that you can meet your needs. When you see an opportunity to take the one-up position, your mammal brain rewards you with the good feeling of serotonin (Raleigh, McGuire, Brammer, Pollack, & Yuwiler, 1991). We can easily see this in others, even though we reframe it in ourselves.

The mammalian brain evolved to compare itself to others, and hold back if it is in the weaker position. Avoiding conflict with stronger individuals is more critical to survival than any one meal or mate. When a mammal sees itself in the stronger position, the safe feeling of serotonin is released. But it is metabolized in a few minutes, which is why the mammal brain keeps scanning for more opportunities to be in the one-up position (Palmer & Palmer, 2001). You may insist you do not compare yourself to others or enjoy a position of social importance. But if you filled a room with people who said that, they would soon form a hierarchy based on how much disinterest each person asserts. That is what mammals do, because each brain feels good when it advances its unique individual essence.

Cooperation is one way to gain a position of strength, and larger-brained mammals will cooperate when it meets their needs. They work together to advance their position in relation to common rivals, and serotonin is stimulated when they succeed (Breuning, 2015). The pursuit of social importance may threaten social alliances at times, but it strengthens social alliances at other times. Each brain is constantly weighing complex trade-offs in its path to survival.

Each serotonin spurt connects neurons that tell you how to get more in the future. The serotonin of your early years builds myelinated pathways that play a big role in your social navigation through life. These pathways generate expectations about which behaviors are likely to enhance social power and which behaviors might threaten it. Every researcher has expectations about which actions might bring respect or lose respect. One research outcome might trigger the expectation of social reward while another set of data might trigger social pain. It is easy to see why people go toward one slice of information and avoid another without conscious intent. And it is easy to ignore one's own efforts to compare favorably, even as we lament such efforts in others.

Cortisol

The mammalian brain releases the bad feeling of cortisol when it encounters a potential threat (Selye, 1956). Bad feelings promote survival by commanding attention. For example, a gazelle stops grazing when it smells a lion, even if it is still hungry. Cortisol motivates an organism to do what it takes to make the bad feeling stop (Sapolsky, 1994).

Cortisol is the brain's pain signal, but waiting until one is in pain is not a good survival strategy. That is why the brain is so good at learning from pain. Each cortisol surge connects neurons that prepare a body to respond quickly to any input similar to those experienced in a moment of pain. The brain evolved to anticipate pain because your prospects fall quickly once a lion's jaws are on your neck.

Social pain triggers cortisol. In the state of nature, social isolation is an urgent survival threat. Cortisol makes a gazelle feel bad when it wanders away from the herd, even when it is enjoying greener pastures. Cortisol creates alarm in a monkey who experiences a loss of social status because that is a threat to the monkey's genetic survival prospects. Conscious concern for one's genes or one's status is not needed to get the cortisol flowing. Natural selection built a brain that warns you with a bad feeling when your prospects encounter a setback. You may try to ignore it, but if you do not act to relieve the perceived threat, the alarm is likely to escalate.

A big brain brings more horsepower to the task of identifying potential warning signals. Cortisol turns on when we see anything similar to neurons activated by past cortisol moments. It is not surprising that people are so good at finding potential threats, and so eager to relieve them. And it is easy to see how social threats can get our attention as much as we presume to disregard them.

The Survival Urge in Science

Scientists are presumed to be indifferent to social rewards and threats as they comb the world for empirical truths. But like all mammals, scientists can easily see the potential for rewards and threats in their information environment; and like other mammals, they respond neurochemically to this information.

For example, dopamine is released when a scientist sees an opportunity to step toward a reward. Oxytocin is released when scientists cooperate with peers. Serotonin is released when an investigator gets respect. Cortisol is released when a scientist sees an obstacle to rewards, cooperation, or respect. These responses are shaped by neural pathways built from unique individual life experience, but the urge to do things that relieve cortisol and stimulate happy chemicals is common to all brains.

While our responses depend on our individual pathways, those pathways overlap to the extent that the experiences creating them overlap. Science training is a common set of experiences that help to wire individuals with common responses. For example, professional training prepares an individual to invest enormous effort in a long series of tasks in anticipation of distant rewards (social and/or material). It prepares an individual to collaborate within a particular theoretical framework. And it builds circuits that confer respect in specific ways and expect to receive respect accordingly. In short, science training builds specific expectations about how to gain rewards, social trust, and respect, and thus stimulate dopamine, oxytocin, and serotonin.

Expectations about threat and cortisol relief are likewise shaped by professional training. The credentialing process of each discipline prepares the mind to recognize potential threats to the discipline and respond in a way that promotes the well-being of the discipline. This need not be said in words because expectations are real physical pathways in the brain. Scientists surge with cortisol when they see a potential threat to their discipline and their place within it, and like any mammal, they are motivated to do what it takes to relieve that cortisol.

Fortunately for the state of knowledge, a scientist can gain rewards, cooperation, respect, and threat relief through objective empirical analysis. But even if this works in the long run, it does not always work in the short run. Thus, every scientist can recognize opportunities to stimulate immediate positive neurochemistry in ways that violate the scientific method.

It would be easy to point accusing fingers here, given the universality of these responses. But our brains are already skilled at seeing bias in others. The challenge is to recognize these mammalian motivations in one's self. In that spirit, I present two empirical biases I discovered in my own life. Before that, let us return to the Semmelweis story, where short-run motivations prevailed and in the long run we're all dead.

The Survival Brain's Potential for Bias

The hand-washing Dr. Semmelweis was of course interested in his own survival. The colleagues who disdained him were too. Each brain defined survival with networks of associations built from past experience. Those networks make it easy to process inputs that fit, and thus to respond in ways that worked before.

In the state of nature, objectivity promotes survival. To find food and procreate, an animal must interpret cues realistically. However, an animal that looked at the world with fresh eyes each morning instead of relying on old pathways would starve, and be socially ostracized. Old neural pathways equip us to scan the overload of detail that surrounds us and zero in on cues relevant to meeting our needs.

In the natural world, rewards fit old patterns so often that old neural networks are an efficient way to find new rewards. Scientists learn the value of relying on old pathways through lived experience and formal training. Yet, we expect scientists to reject old interpretations instantly when they bias interpretations of new data. Alas the brain did not evolve to instantly discard old circuits. They are real physical changes in neurons that speed electricity to the on switch of reward chemicals and pain chemicals. Hence, it is not too surprising that Semmelweis's peers filtered the new message through their old lenses.

It would be easy to accuse them of greedy preoccupation with their own survival needs at the expense of others. But the germ theory of disease had not been established yet, so Semmelweis's allusion to invisible disease carriers was superstitious nonsense in the science paradigm of his day. Leading doctors claimed that the public needed protection from such dangerous misinformation (Nuland, 2003).

Curing a major killer of the day, "childbed fever" (septicemia), may seem like a huge reward, but without a perceived link between hand-washing and health, there is no expectation of that reward. Doctors could easily anticipate a threat to their respect and social alliances as a result of Semmelweis's findings. The consequent bad feeling would not be offset by the expected good feeling of rewards, leaving doctors with antipathy that they could explain with verbiage unrelated to their own neurochemistry.

One may wonder why Semmelweis persisted in isolation. His biography is full of clues. First, his closest associate died from "childbed fever" after cutting his finger during surgery. This rewired Semmelweis's view of the disease. People often fail to rewire their views in response to new information, but the bigger neurochemical surge, the more the rewiring. Losing a best friend so quickly with such a clear chain of evidence would easily do that.

Second, Semmelweis was not wired to trust the safety of the herd in the way that his peers were. Some people attain professional credentials by cooperating with mentors in their discipline, while others satisfy credentialing requirements by going their own way. Semmelweis had been rejected numerous times by the community of science in his formative years, so he was already wired to rely on his own perceptions by the time the natural experiment with septicemia occurred in his hospital. When he observed that mothers attended to by midwives did not die of the disease the way postoperative doctors did, he was ready to rely on his own survival responses instead of trusting the survival responses of the herd.

If we are angered by his colleagues' indifference to the facts, we must hold ourselves to the same standards. We must be willing to invest our own energy in new information that conflicts with shared expectations, even when it threatens our social support. Often we do not. Often I did not. Here are two examples.

I was trained in International Management at a time when Japanese methods were celebrated and American methods were disparaged. I was wired to effortlessly process information about the glories of Japanese management and the misguidedness of American management. Then one day in 1995, while lecturing to 150 students, I suddenly realized that Japan had been in a deep depression for 5 years. US productivity was booming, and I had not adjusted my rhetoric one bit. Why? It is easy to see the rewards and threat contingent on the new data. My survival was not really at stake because I was a tenured full professor. As hard as it is to admit, I was influenced by the threat that the new facts posed to my whole constellation of expected rewards. To state it more boldly, I feared social sanction. I might have continued to ignore the unwelcome truth if the terror of perceiving my bias midsentence on the stage of a large auditorium had not triggered enough cortisol to connect neurons to sear in the facts.

I was also trained to believe that children are better off in daycare. I put my children in daycare with the belief that "studies show" a neutral or even positive impact. Despite my pretensions to objectivity, I know that I cheered any data that fit my beliefs and disdained any data that did not. Now that the daycare generation is grown and there are causes for concern, I can see the many obstacles to new information. Anyone trained in the social sciences could easily see the potential rewards for findings consistent with the prevailing mindset and the potential threat of contradicting it. A researcher who stumbled on negative effects of daycare might fear reporting them. They could easily repeat the study with adjustments until they got results consistent with expected rewards. And if they did report anomalous findings, that information might get ignored by mass communication channels. They might also get ignored by the science community, leading to a lack of replication and a consensus that the findings are an aberration.

We can never have data on studies not performed, so we can never know the full extent of bias. But we can explore the extent of our own biases. I only noticed my bias on daycare because the survival stakes for my DNA triggered large cortisol surges. Yet, my accumulation of discrepant data over the years has fostered a willingness to notice biases in my own mindset – a paradigm shift on an individual level.

Science Bias Today

Though we aspire to objectivity, we end up seeing the world through the lens of old neural pathways. This lens is hard to notice because it is built from shared experience and thus overlaps with the lens of those around us. Consider, for example, the Rousseauian lens embedded in today's social science. Rousseau asserted that nature is good, and "our society" is the cause of that which is bad. A social scientist who finds evidence to support this presumption can expect rewards. The result is an accumulation of evidence that:

1. Animals are good (they cooperate and nurture each other)
2. Children are good (they grow to perfection automatically, unless miseducated by society)
3. Preindustrial people are/were good (in harmony with nature and each other)

A reader may think these assertions are indisputable facts because the effortless flow of electricity through well-developed pathways gives us a sense of truth. No one notices the neural network they built from repeated experience. No one accounts for their natural anticipation of rewards and pain as they process each new input. We can only have realistic information if researchers feel safe reporting what they find and we feel safe receiving it. Here are some simple examples of data being shaped to fit the Rousseauian framework, despite the shared presumption of objectivity.

1. Animals are naturally good Mountain lions are endangered in the hills around my hometown, and measures to protect them are in effect. Every effort is made to rehabilitate an injured mountain lion; but the animal cannot be returned to the wild when it recovers because it would be killed instantly by the lion that dominates the territory it is released into. This raises an uncomfortable problem. No one wants to admit that animals routinely kill intruders (Lorenz, 1966). "Only humans kill" is a widely shared belief, and a person is likely to get ostracized from a social alliance if they violate such a core belief. Just thinking of that risk is enough to trigger a neurochemical alarm that discourages a person from stating obvious facts. So animal rescuers struggle to do the necessary without acknowledging the reasons.

For most of human history, animal conflict was observed first hand. It is true that animals rarely kill their own kind, but that is because the weaker individual withdraws to save itself (Ardrey, 1966). Animals are at the edge of conflict a lot because asserting promotes their genes. Today's researchers "prove" that animals share and empathize by crafting "studies" that ignore all behaviors except that which supports the message of animal altruism (de Waal, 2010). Every researcher understands the reward structure, and no researcher wants to invalidate his or her prior investments of effort. Researchers believe they are motivated by the greater good rather than the urge to seek rewards and avoid pain because those words are part of the learned framework and people tend to believe their verbal explanations of their motives. If no one will risk reporting animal conflict, then we can say there is "no evidence" of animal conflict, and it will be true.

2. Children are naturally good Children flourish if left to their own impulses according to widely held beliefs in social science (Montessori, 1949). Any developmental problems that occur are quickly explained as a failure of "our society," and letting a child do what feels good is the widely embraced solution (Rousseau, 1762). Credentialed professionals point toward "proof" that fun is the core of learning, and they know they will be rebuked if they expect a child to do something unfun (Gatto, 2008). If the student has not learned, the teacher has not made it fun.

For most of human history, survival depended on children pulling their weight. Each child carried water, firewood, or a younger sibling, as parents deemed necessary, whether it felt good or not. Children looked for ways to make it fun, but adults did not substitute children's fun-meter for their own judgment. A young brain learned survival skills not by following its bliss but by being held accountable for essential tasks – often harshly. Experiencing the repetitive, backbreaking labor of one's parents (a challenging concept explained in Sect. 3 below) built core self-management skills such as focusing attention on steps that meet needs.

We have been trained to believe that children frolicked happily in the past. If you violate this shared presumption, it is hard to survive as a member in good standing of a social-science profession. Just taking a step toward information that violates a shared framework is difficult because one's neurochemical alarm signals the risk. It is not surprising that people step where rewards are expected, without consciously telling themselves that in words. The result may be more research on how to make things "fun," and more children who do not learn basic survival skills.

3. Preindustrial societies were/are good Traditional people only worked a few hours a day, according to social scientists, and spent the rest of their time making art, making love, and making their group-mates feel valued and understood (Pink, 2011). Research that enhances this paradigm gets recognition. Research that conflicts with it gets ignored, ridiculed, or attacked. This reward structure surrounds a researcher's choices about where to invest their energy.

The higher form of this paradigm offers higher rewards: the concept that traditional people never worked at all, because work is what you have to do, and early humans could survive by doing only what felt good (Diamond, 1987). Researchers can support this assertion with inferences about the time period before recorded history but after the separation between humans and apes – the time when no data are available except that produced by social science itself. Evidence is also easy to generate by defining the labor of prehistory as "creativity" or "fun." Of course, foraging feels good when you are hungry, so the premise is true as long as you ignore all the facts that do not fit.

A researcher has no reason to investigate the pain and suffering of the past if there is no expected reward. They have reason to fear social pain if they step toward evidence that our ancestors did mind-numbing labor in service to tyrants in hopes of getting protection from endless attackers. The result is the prevailing belief that life is sheer hell today, compared to past times. One wonders how those aggrieved by modern society would feel about vermin-infested open-pit toilets and neighboring tribes stealing their food stocks and their daughters.

The Greater Good Tautology No one likes to imagine themselves sifting data for opportunities to meet their own survival needs. It feels better to imagine one's self serving the greater good. The verbal brain can always define the greater good in ways that rationalize the mammal brain's quest to meet its needs. Semmelweis's critics invoked the greater good without acknowledging their own survival motives. Today's science community focuses on verbal abstractions about the greater good and overlooks the role of neurochemical survival responses in their thinking. This makes it hard for individuals to recognize biases that may occur. The brain is designed to go toward things that feel good, and believing in the superiority of one's ethics feels good. But no brain is indifferent to rewards and pain because that information drives our operating system. If we want good data, we are better off understanding our brain than masking our biases with abstractions about the greater good.

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