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What Is a Habit?

THINK FOR A MOMENT about your morning routine. Mine involves walking downstairs from my bedroom, turning on the espresso machine, putting together my breakfast (plain yogurt, blueberries, and nuts), and firing up my laptop to check email, social media, and news. What is so remarkable is that we can perform these kinds of routines without actually *thinking* about what we are doing—very rarely do I actually entertain conscious thoughts like "now I need to take out a spoon and scoop the yogurt into the bowl" or "now I need to walk from the refrigerator to the counter." When people think of habits, they often jump immediately to "bad habits," like smoking, drinking, or overeating, or "good habits," like exercise or brushing our teeth. However, these are just the visible tip of a huge iceberg of habits that each of us has. And if you think a bit about what life would be like without them, it's pretty clear that we would quickly succumb to decision paralysis.

In his moving book *The Emperor of All Maladies: A Biography of Cancer*, Siddhartha Mukherjee describes how we should not think of cancer as something separate from our bodies, because in fact it is a reflection of exactly the biological functions that keep us alive:

> Cancer, we have discovered, is stitched into our genome. . . . Cancer is a flaw in our growth, but this flaw is deeply entrenched in ourselves. We can rid ourselves of cancer, then, only as much as we can rid ourselves of the processes in our physiology that depend on growth, aging, regeneration, healing, reproduction. (p. 462, Kindle edition)

We should think of habits in much the same way. We will see how the stickiness of habits can make behavior very hard to change, but it is exactly this stickiness that makes habits essential for navigating our complex world so effectively.

The Poet of Habits

William James was the first great American experimental psychologist. Whereas his brother Henry James is renowned as one of the greatest American novelists, William James stands as one of the greatest thinkers ever to have written about the human mind. In his 1890 book *Principles of Psychology*,[1] James wrote what remains one of the most compelling descriptions of habits and their importance, providing a particularly striking picture of just how essential habits are to our everyday lives:

> The great thing, then, in all education, is to *make our nervous system our ally instead of our enemy. . . . For this we must make automatic and habitual, as early as possible, as many useful actions as we can. . . .* There is no more miserable human being than one in whom nothing is habitual but indecision, and for whom the lighting of every cigar, the drinking of every cup, the time of rising and going to bed every day, and the beginning of every bit of work, are subjects of express volitional deliberation. Full half the time of such a man goes to the deciding, or regretting, of matters which ought to be so ingrained in him as practically not to exist for his consciousness at all. (p. 122, emphasis in original)

For James, the idea of "habit" was defined at its core in terms of *automaticity*—that is, the degree to which we can perform an action automatically when the appropriate situation arises, without consciously entertaining the intention to do it. Automaticity often only becomes apparent when it makes us do the wrong thing. Nearly all of us have had the experience of intending to make an unusual stop on the way home from work (the dry cleaners is a common example), only to get home and realize that we forgot to make the stop, because our behavior was carried by the automatic habits that we have built up over driving the same route many times. Just as cancer is the dark side of our cells' mechanisms for growth, errors like these are the flip side of our usually safe reliance on habits.

James's notion of making our nervous system "our ally instead of our enemy" becomes particularly clear when we acquire a new *skill*, by which we mean a highly tuned ability that we can perform without effort—very similar in fact to the concept of a habit. Nearly every aspect of our interactions with the artifacts of our world, from driving a car or riding a bicycle to using a computer keyboard or smartphone touchpad, involves skilled behaviors that develop over a long period of time. Perhaps one of the most unique human skills is reading. Written language has only existed for about 5000 years, a tiny portion of the evolutionary history of humans, and while nearly all humans learn to understand and speak their native language with seemingly no effort, reading is a skill that takes years of education and practice to acquire. However, the skill of reading becomes automatic once it is acquired, in the sense that we can't help but process the meaning of text that we see. The automatic nature of reading is seen in the well-known *Stroop effect*, in which a person is shown words written in colored ink and asked to name the ink color as quickly as possible. If we compare how long it takes to name the color of a word when the text matches the color (for example, "red" written in red) versus the same color with a different word ("blue" written in red), we see that people are invariably slower to name the color when it mismatches the word—which means that even when the written language is irrelevant or even harmful to the task at hand, we can't help but read it. In this way, skills are often very similar to habits in that they are executed automatically without any effort or awareness. As we will see in the next chapter, this relationship between habits and skills has played a central role in our understanding of the brain's systems that support both habits and skills.

The Zoo of Habits

If habits are truly a fundamental aspect of our mind's functioning, then we should expect to see them everywhere we look, and indeed we do. Each of us has a large number of *routines*—that is, complex sets of actions that we engage automatically in a particular context, often daily but sometimes more infrequently. We make coffee in the morning, we drive a particular route to work, we set the table before dinner, and we brush our teeth before going to bed. Although each of these actions serves a particular purpose, very rarely do we consciously think about our goal as we do them, or even about the fact that we are doing them at all. The mindless nature of these routines is at odds with a long-standing idea in psychology that our actions are driven primarily by our goals and beliefs.[2] However, research by psychologists Judith Ouellette and Wendy Wood has shown that many routine behaviors (especially those we engage in daily) are better explained in terms of how often they have been done in the past (that is, the strength of the habit) rather than in terms of goals or intentions.[3]

While routines can truly make our brain "our ally instead of our enemy" as James proposed, other habits often seem more like mindless responses to a particular cue or situation. Sometimes these don't seem to serve any apparent goal at all, as when a person chews their fingernails or twirls their hair. In other cases, as when we devour a bowl of popcorn on the couch while watching a movie, the action seems to be in service of a goal, but again our intentions don't seem to come into play, and we often realize that we have eaten much more than we would have ever intended. As we will see below, the idea that habits become detached from goals or intentions is one of the central concepts behind our knowledge of how habits work, and we have an increasingly deep understanding of how this comes to be.

The habits we have discussed so far all involve physical actions, but it's important to point out that we can also have *habits of mind*. My wife and I, having been together almost 30 years, will often find that we end up thinking exactly the same thing in particular situations, or finishing each others' sentences when telling a story. Our shared experience over decades has led us to develop a set of shared mental responses to common situations. In other cases, habits of mind can become deeply disruptive, as when individuals suffering from obsessive-compulsive disorder become disabled by particular thoughts that they cannot keep out of mind.

Finally, emotional responses to particular situations can also become habitual. For example, many people develop an intense fear reaction to the prospect of speaking in public, as I did early in graduate school. Just as habitual actions are triggered by particular situations, the psychological and physical responses that occur in a phobia can be thought of as an "emotional habit."

Habits and Goals

While the gamut of habits thus spans from action to thought, most of the research on habits has focused on relatively simple actions. Further, while our interests are ultimately in understanding how habits work in humans, much of the research I discuss has been carried out in species other than humans, particularly in rodents (rats and mice). This is in part because creating new habits in the laboratory in humans is just plain difficult due to the amount of time and experience that is required; because rats live in the laboratory, they can be exposed to training for hours each day. In addition, our scientific interests are often focused on "bad" habits, such as substance use or overeating, but it would not be ethical to give a human a new bad habit for research purposes. Fortunately, the organization of the rodent's brain is similar enough to the human brain that there is much to be learned from studying them, though we always have to keep in mind that there are differences as well. In addition, rodents are useful species in which to study habits, because they are relatively single-minded, at least when a member of the opposite sex is not present: they just want to eat. More recently, an increasing amount of research has been done using mice instead of rats because of the ability to use powerful genetic tools for dissecting and controlling brain function that are more readily available for mice than rats, which I describe later in the book.

One standard way that rodents are studied is to put them in an *operant conditioning chamber* (Figure 1.1), often called a "Skinner box" after the psychologist B. F. Skinner who popularized them for studying how rats learn. The box has a way for the animal to respond (usually a lever

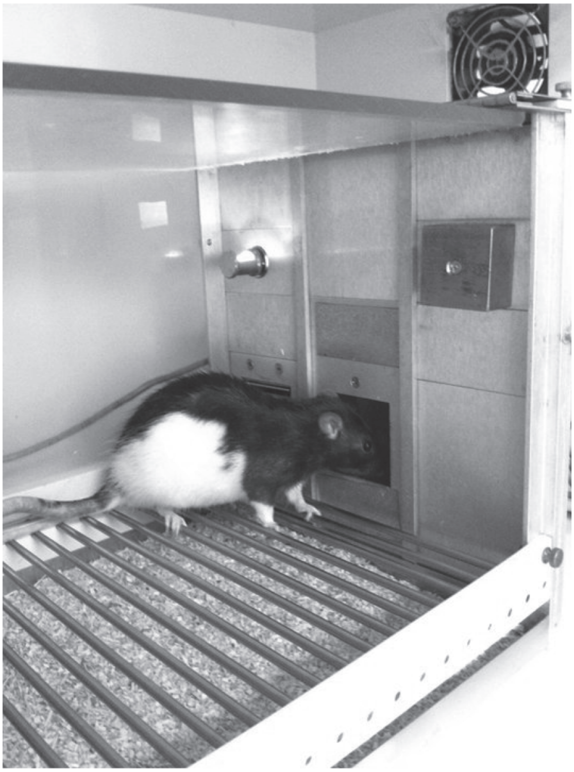

FIGURE 1.1. A rat poking its nose in an operant conditioning chamber (better known as a *Skinner box*). (Photo courtesy of Aaron Blaisdell)

that they can press or a port they can poke their nose into), along with a food dispenser that can drop pellets of food for the animal to eat. The box is configured so that a certain number of presses of the lever (or alternatively, presses within a certain amount of time) result in food being dropped. Rodents will fairly quickly learn to press the lever in order to obtain food, and this is the basis of many of the studies that have been done to examine how habits are learned.

Let's say that a researcher trains a rat to press a lever to obtain food over many days, so that when they are put into the box they immediately start pressing. How would we know whether this behavior is a "habit"? One influential answer to this question was provided by the psychologist Anthony Dickinson of Cambridge University. According to Dickinson, there are two reasons that a rat might continue to press a lever once it has learned to do so. On the one hand, the rat might be pressing the lever because it has in mind the goal of getting some food, and it knows that pressing the lever will obtain the reward; because this behavior is directly in service of a goal, Dickinson called it *goal-directed* action. On the other hand, the rat may simply press the lever because that's what it has learned to do when placed in the Skinner box, even if it doesn't have the goal in mind. This is what Dickinson refers to as *stimulus-response*, or habitual behavior. Based on this distinction, Dickinson devised a clever way to determine whether a rat had a goal in mind when it was pressing: eliminate the value of the goal and see whether the animal continues performing the behavior. For example, let's say that the reward is a pellet of rat chow. We can devalue the reward by feeding the rat a bunch of chow just before we put it into the Skinner box, so that it's sick of that particular food. If the rat no longer presses the lever after having been satiated, then we can be sure that its lever pressing is done with the goal in mind. On the other hand, if the rat continues to press the lever even when it doesn't want the chow anymore, then we can be sure that the lever pressing is a habit, which for Dickinson means that it is an action that is evoked by a particular stimulus (in this case, the presence of the lever) without any goal in mind. What Dickinson and his colleagues found was that early in the process of learning, the rats behaved as if they were goal directed: when the reward was devalued, the rats stopped pressing the lever. However, with additional training, the rats' behavior became habitual, such that they continued to press the lever even though they didn't want the reward. This transition from early reliance on goal-directed control to later reliance on habitual control is a pattern that we will see repeatedly in our examination of habits.[4]

Thus, habits differ from intentional, goal-directed behaviors in at least two ways: they are automatically engaged whenever the appropriate stimulus appears, and once triggered they are performed without regard to any specific goal. Now let's ask why evolution would build a brain that is such a habit machine.

Why Do We Have Habits?

It's easy to forget that many aspects of the world that we inhabit are remarkably stable. The laws of physics remain the same from day to day, and the structure of the world also remains largely consistent—your friends don't start speaking a new language to you out of the blue, and the steering wheel on your car works pretty much the same way every day. On the other hand, there are aspects of the world that change from day to day, such as the particular spot where a person parks their car, or the weather they need to dress for that day. Other aspects of the world are consistent in our local environment but differ in other environments; for example, when I drive a car in the US, I need to drive on the right side of the road, whereas if I were to drive on a trip to the UK, I would need to drive on the left.

Our brains are thus stuck on the horns of a tricky dilemma. On the one hand, we would like for our brain to automate all the aspects of the world that are stable so that we don't have to think about them. I don't want to spend all of my time thinking "stay in the right lane" when I am driving my car at home in the US, because that's an aspect of my local world that is very stable. On the other hand, when things change in the world, we want our brain to remember those things; if a particular road is closed for construction, I need to remember that so that I can avoid it on my way to work. An even more challenging wrinkle is that the brain isn't told which things are stable and which are changing—it has to learn this too, and in particular it needs to make sure that we don't change too quickly. For example, if I were to drive a car in England on vacation for one day, I wouldn't want to come home with my brain rewired to drive on the left side of the road. The computational neuroscientist Stephen Grossberg coined the term "stability-plasticity dilemma" to describe this conundrum: How does the brain known how to change at the right time without forgetting everything that it knows?

In Chapter 3 I delve much more deeply into how habits are an essential aspect of the brain's solution to the stability-plasticity dilemma and how this relates directly to the stickiness of habits. The basic strategy that evolution has used to solve the dilemma is to build multiple systems into the brain that support different types of learning. The psychologists David Sherry and Daniel Schacter proposed that these separate brain systems evolved because they were needed to solve a set of problems that are "functionally incompatible"—that is, problems that simply cannot be solved by a single system. They argued that the brain's *habit system* evolved to learn those things that are stable (or *invariant*) in the world, whereas another memory system (known as the *declarative memory system*) evolved to allow us to learn the things that change from moment to moment. The habit system lets us learn how the pedals on the car work (which usually never changes), while the declarative memory system lets us remember where exactly we parked our car today (which changes from day to day). In the next two chapters, I go into much more detail about how these systems work in the brain and how they relate to one another.

Understanding Behavior

Any particular choice or action that we make belies a massive amount of computation going on in our brain. Because I spend much of this book discussing the various factors that drive our behavior, it's useful to have a framework in place for understanding how we behave. Figure 1.2 shows a schematic that guides the organization of this book.

Everything we do is influenced by our environment, which allows some kinds of choices and forbids others, and also presents us with stimuli that can trigger our desires and habits. As we will see Chapter 8, many of the most effective ways of changing behavior involve changing the environment. Once we are ready to make a choice, there are several factors that can influence our decision. First, we have our long-term goals—what do we want to do in the future? Second are our immediate desires. These are the things that we want right now, without regard to how they align with our long-term goals. Finally, we have our habits. These are the behaviors that we have learned through experience and that we automatically engage in without thinking.

To make this concrete, let's say that I am attending a party at a colleague's house, to which I drove my own car, and my colleague offers

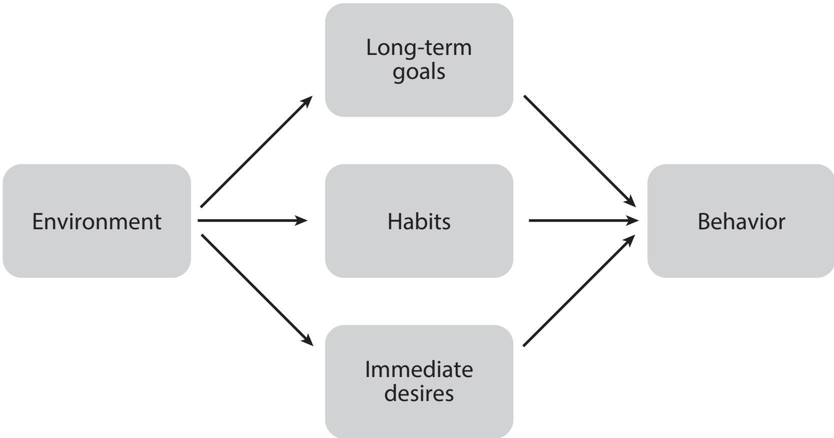

FIGURE 1.2. A schematic for understanding the various factors that go into a choice.

me a cocktail. I like cocktails, and my immediate desire is to say, "Thanks, I'd love one." However, I have the longer-term goal of remaining sober so that I can drive home (which relates to my even longer-term goals of avoiding accidents and staying out of jail), which would lead me to decline the cocktail and drink something more goal relevant instead, such as a glass of water. However, depending on my experience, I might have a habit of drinking cocktails at parties and could find myself with a cocktail in my hand despite my long-term goals. As we will see, all of these different components of a choice are important to understand how we can more effectively change behavior.

A Road Map for Understanding Habits and Behavior Change

This book is broken into two parts. The first part, "The Habit Machine," outlines what exactly scientists mean when they refer to a "habit" and where habits come from in the brain. Different scientists define habits in different ways, but most agree on a few basic characteristics. First, a habit is an action or thought that is triggered automatically by a particular stimulus or situation—it doesn't require any conscious intention on our part. Second, a habit is not tied to any particular goal; rather, habits are engaged simply because of their trigger. This is important, because it means that the habit persists even if the reward that created it is no longer present. Third, habits are *sticky*: they come back despite our best efforts to suppress them, often when we are at our weakest point.

In the next chapter, I turn to describing the brain systems that underlie habits and how they relate to other kinds of learning and memory. Here we will first see that the systems in the brain that underlie the learning of habits are distinct from the systems that help us form conscious memories for the past. We will also have our first encounter with the neurochemical that might be viewed as either the star or the villian of the habit saga, depending on your perspective: dopamine. In particular, we will see how dopamine plays a central role in strengthening actions that lead to reward, ultimately setting the stage for the development of habits.

In Chapter 3, I turn to the research on why habits are so sticky. Here we will see that a number of different features of habits conspire to make them particularly persistent. On the one hand, habits become increasingly unitized over time; what was once a set of actions that each required our conscious attention and effort becomes a single unit of action that requires little added thought or intention. On the other hand, the triggers for those habits become increasingly powerful and increasingly draw our attention. Together these mechanisms provide a recipe for behaviors that become very difficult to change.

In Chapter 4, I discuss how the different memory systems in the brain work together to let us behave in an intelligent way. Here we will see that our behavior arises from a competition between different learning systems in the brain. I also dive deeply into explaining one of the best-accepted theories that describes the computations the brain performs in order to learn new habits, known as *reinforcement learning*. We will see how different forms of reinforcement learning can give rise either to habits or to planful (goal-directed) behavior. I also describe how higher-level goals can become habitual, moving beyond simple action habits to more complex kinds of habits.

When many people think of habits and why they are so hard to change, their mind often turns immediately to the ideas of *self-control* and *willpower,* which I explore in Chapter 5. This story centers heavily around the brain's prefrontal cortex, which is the center that helps us resist immediate temptations and instead behave in service of longer-term goals. There are actually several different facets of self-control, which rely upon somewhat different systems in the brain. I also discuss the concept of willpower, which you will see plays a very different role than our intuitions would lead us to expect.

The most serious and often tragic impact of habits is often seen in addictions, which I turn to in Chapter 6. It is no accident that all drugs of addiction cause unnaturally strong activation of the dopamine system, given its central role in habit formation. Beyond drugs, I also discuss the idea that one can become addicted to food or digital devices. I also discuss some recent neuroscience research that sheds light on the interesting question of why some drug users become addicted but many others do not—research that suggests that the answer may lie in a biological luck of the draw.

The second part of the book, "Coming Unstuck," focuses on what science tells us about how to change behavior most effectively, realizing that habits will always remain immensely strong. In Chapter 7, I describe how the difficulty of behavior change underlies a number of our most important and difficult public health problems. I outline the shortcomings of previous research on behavior change, and describe a new approach that is attempting to change this by focusing on the basic mechanisms that support behavior change.

Many different strategies have been suggested to help change behavior, and in Chapter 8 I discuss research into the effectiveness of many of these approaches. Some of the strategies are supported by science, but for many of them the science is just too weak to support their use. In Chapter 9 I discuss some possible avenues for future interventions based on neuroscience research. None of these have been implemented yet at any sort of scale, but some of them provide promise for the future. I wrap things up in the epilogue, where I offer a synthesis of what the science tells us about the prospects of improving our ability to change our behavior, particularly in the context of major challenges such as the COVID-19 pandemic and the climate crisis.

Be forewarned: I don't have any "easy tricks" to offer for breaking bad habits. In fact, many of those magic solutions for habits that you've read about in other books tend to vanish when we look at the real science. Instead, you will walk away with a deep understanding of why habits are so sticky and hopefully with a few well-supported ideas about how to improve the chances of making successful changes.

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