2

Overview about the Brain

2.1 Brain and Mind Myths

The human brain began evolving well before any hominids walked the Earth and has further evolved over thousands of generations as our ancestors survived the harsh life in the African savanna. However, our modern life is very different from prehistoric times, and we face many problems that are new for our brain in terms of the relatively slow scale of evolution. Therefore, understanding the wonders and limitations of our brain as it navigates the complexity of the modern world is useful for improving our decision-making on a daily basis. And this is what we're going to talk about all throughout the first part of this book. I will mostly limit myself to describing what should be the most useful things to know in the context of game development though, so if you are curious about the subject as applied to broader situations, you will find some useful tips in the book *Mind Hacks* (2005) from cognitive scientist Tom Stafford and engineer Matt Webb.

Even though we are only scratching the surface of the brain's mysteries, fascinating discoveries about how it works have been made in the past century. They are, however, sadly tempered by countless myths that pollute our media. I won't go through all of these myths because other authors have already covered them in wonderful detail (e.g., Lilienfeld *et al.* 2010 and Jarrett 2015), but I will briefly describe the ones that are the most relevant to video game development and which I believe you need to know about before we go any further.

2.1.1 "We Only Use 10% of Our Brains"

It is very tempting to believe that we have untapped brain powers that can be unleashed by anyone who has the key. (I've heard that some companies will give it to you in exchange for money.) In reality, even doing something as simple as clenching your fists takes more than 10% of your brain to execute, and modern brain imagery shows activity throughout the entire brain whenever we do something—and even when we don't do anything. The brain does, however, have the capacity to reorganize itself, such as when you learn to play a musical instrument or after a brain injury. The fact that the brain manifests such flexibility is a wonder by itself and offers you massive amounts of potential to learn new knowledge and skills; so, don't be too disappointed that you are already using much more than 10% of your brain. You would be in a very sad state if you weren't.

2.1.2 "Right-Brained People Are More Creative than Left-Brained People"

"Develop your right brain to unleash your creativity!" as the story goes. It is true that both hemispheres of our brain are different and are not necessarily used equally when we accomplish certain tasks, but the "left-brain right-brain" distinction is mostly false. For example, you might have learned that language is mostly dominated by left hemisphere activity. Well, generally speaking, the left hemisphere is in fact *relatively* better at generating words and applying grammatical rules while the right hemisphere is *relatively* better at analyzing prosody (speech intonation). However, for any given activity, both hemispheres work together in harmony. Suggesting that the left hemisphere is the logical one while the right hemisphere is the creative one is a gross and inaccurate simplification. Both hemispheres are connected through the corpus callosum, a large pathway of nerves that allows both hemispheres to share information. So even if you were tempted to enhance your creativity by stimulating your right hemisphere, it would be nearly impossible to accomplish such a discriminatory thing—unless you are a split-brain patient with a severed corpus callosum and you artificially received input only through the left side of your body (or through the left side of your fixation point in the case of vision). In that very specific case, information would then be processed only by your right hemisphere. There are actually neuropsychology labs that do test split-brain patients that way, but you have to admit that this is far from the seducing right-brain story lines some people would like you to believe. Don't worry though; it wouldn't be useful anyway given that there is no scientific evidence that the hemispheres have "creative" or "logical" specializations. So we can stop romanticizing our right (or left) hemisphere and be one again, whether you are aspiring to be more creative or more logical.

2.1.3 "Men and Women Have Different Brains"

We love to find simple reasons that would explain our differences, don't we? It is admittedly difficult for a man and a woman to make their romantic relationship survive the tumults of life. So let's blame it on some neurological differences to ease our cognitive dissonance instead of blaming it on our own mistakes and lack of empathy! But you know what? Homosexual couples probably have the same difficulties as heterosexual couples do. (I only say "probably" because I do not have any statistics to back my claim, but I'm ready to take a bet on this one.) It is true that the average female brain is not exactly the same as the average male brain when we compile the brain imagery of many people, but they are much more similar than they are different. In fact, there usually is a greater difference among the brains of people of the same sex than between the sexes. No, males and females do not come from different planets, not even rhetorically. There is no scientific evidence, for example, that women can multitask better than men or that they are "prewired" to master language whereas men are "prewired" to master math or park a car. Even if there are *some* differences in brain wiring and *some* behavioral differences between men and women, we cannot link the neurological differences to the behavioral ones when considering cognitive skills. Most of our cognitive differences—such as our performance in science or language—are likely due to our level of practice of a particular skill and to the cultural environment (stereotypes) and social pressure we develop within.

2.1.4 Learning Styles and Teaching Styles

You might believe that you have a preferred learning style and that you will learn better if teaching occurs within that style. For example, you might think that you learn better when taught with visual information rather than verbal information because you are a visual learner. One of the issues with the concept of learning styles is that it's not necessarily easy to measure what is one's preferred learning style. Another issue is that the criteria determining what sort of learning style we are talking about are often all over the place. Are you a right-brained person? An analytic person? A visual person? The idea for training programs is, of course, to find a classification that will resonate with you. You're unsure if you're a left-brained person? How about matching the teaching style with your score on the Myers-Briggs Personality Test? By the way, the Myers-Briggs test is not a scientifically validated test (quite the contrary), so you can play with it if you find it fun, but please do not use it for any important purpose such as hiring. One last issue with the concept of learning styles is that there is actually no solid scientific evidence that you will learn something better if the teaching style matches your learning style preference (assuming you know what your preferred learning style is). Research has shown that, although people differ in their aptitudes for different kinds of thinking and for processing different types of information, there is no indication that the application of learning styles actually enhances learning. Furthermore, some studies have even contradicted the idea that instruction is more effective when the teaching style matches the preferred learning style (Pashler *et al.* 2008), and the concept of learning styles can in some cases even be damaging. However, there *are* ways to design a teaching environment that can facilitate learning, which I will describe throughout this book. One of the most important things is to make the teaching meaningful and to repeat the teaching in different contexts and activities. However, and despite their broad appeal and adoption, "learning styles" themselves have not been found to be a suitable concept for improving learning.

2.1.5 "Video Games Are Rewiring Your Brain and Digital Natives Are Wired Differently"

Your neural networks are constantly rearranging themselves depending on the environment and your interaction with it. This is why all the articles that you see that say something like, "Such and such (say, the Internet) is rewiring your brain" are simply dramatic ways of stating the obvious because pretty much everything you do, perceive, or think about will "rewire" your brain—watching a movie, reflecting on the latest article you read, practicing piano, and so on. Rewiring is not even the right term to use because the brain is not hardwired in the first place. The brain—even if it does have computational powers—is not a computer. Our brain is plastic; it constantly changes throughout our life (although it becomes less plastic as we age), and new synaptic connections are created while others are lost. There is also a tendency to consider "digital natives"—a term coined by Marc Prensky (2001) to describe the millennial generation who grew up with digital technology such as the Internet and video games—as being wired differently than older generations (who are sometimes also called "digital immigrants"). Although we are all wired a bit differently depending on our environment and our interaction with it that does not mean that there are cognitive or behavioral differences between the millennials and previous generations. For example, it's not because millennials are used to texting while doing other activities such as reading that they are better at multitasking than other generations. They are not (see Bowman *et al.* 2010) and that's because their brains function overall like any other *Homo sapiens sapiens* on the planet today or back in prehistoric times; therefore, they face the same limitations. (See Chapter 5 in which I describe the limitations of human attention.) What is true though is that millennials, and every other generation younger or older, have different expectations and a different mental model for the products they are interacting with, such as a video game. However, anyone—millennial or otherwise—who has spent countless hours playing shooter games will not have the same expectations or mental model as someone who prefers to spend their time playing *Minecraft*. Therefore, again, the reality is much more nuanced than the clickbait titles would like us to think.

2.2 Cognitive Biases

As if dealing with brain myths was not enough, we also need to be aware of how our brains might hinder our own objectivity and capabilities for rational decision-making. To explain what these *cognitive biases* are, let me use the more

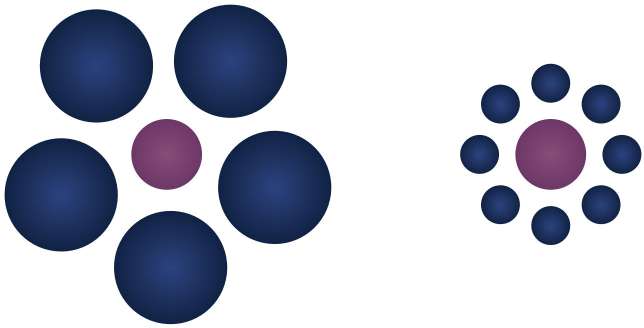

Figure 2.1

Optical illusion.

familiar example of optical illusions. In the illusion presented in Figure 2.1, the two central purple circles have the same size—although we perceive the central circle on the left as being smaller than the one on the right because of their relative sizes compared to the other circles surrounding them. Well, the same principle applies to cognitive biases. Cognitive biases—or cognitive illusions—are patterns of thought that bias our judgment and our decision-making. Just like optical illusions, they are very difficult to avoid even if we are aware of them. The groundbreaking psychologists Amos Tversky and Daniel Kahneman were the first ones to study cognitive biases (see Tversky and Kahneman 1974, and Kahneman 2011). Specifically, they demonstrated that the human mind uses shortcuts of intuitive thinking (heuristics or rules of thumb in judgment) that result in making predictable mistakes in our reasoning. Professor of psychology and behavioral economics Dan Ariely in his book, *Predictably Irrational* (2008), went into more detail on how cognitive biases impact our everyday lives, inducing systematic errors in our reasoning and in our financial decision-making. For example, "anchoring" is a cognitive bias that is somewhat comparable to the optical illusion presented in Figure 2.1: We have a tendency to rely on previous information (the anchor—such as the size of the circles surrounding the purple central circle in the optical illusion) to make a judgment about a new piece of information by comparing one to the other. Marketers use anchoring to influence our decisions. For example: You see a video game blockbuster on sale for $29 with an initial price of $59 next to it. In that case, the $59 price tag represents the anchor (often emphasized by a strikethrough effect applied to it) to which you compare the current price. This makes you recognize that it is a good deal, and this might sway you into buying this title over another one at the same price of $29 but that is not on sale. Even though the cost is the same, the game that is not on sale might seem less interesting because it doesn't make you feel that you are saving money ($30) compared to the game on sale. Similarly, the same price of $29 can appear less of a good deal if there are other blockbusters on sale for $19 and, therefore, representing even better deals. Maybe you will end up buying a game that you were less interested in just because it offered a better deal, or maybe you will buy more games instead of the one(s) you were initially interested in because you just cannot miss this compelling opportunity to make such a good purchase. In the end, you might even spend much more money than your video game budget allows. This is probably the main reason why I see many of my friends complaining on social media whenever some *Steam* sales happen; they just cannot help buying all those games at such a great price, even though they know they will probably never have the time to play most of them. We tend to compare things to one another to make decisions, and it influences our judgment. The worst part is that we are mostly unaware of being influenced by these biases. I'm not going to list them all here because there are too many, but the product manager Buster Benson and the engineer John Manoogian created the chart shown in Figure 2.2 in an effort to sort and categorize the cognitive biases listed on the dedicated Wikipedia page (see Benson 2016).

Whenever relevant, I will mention specific cognitive biases throughout this book. The chart can look scary and discouraging, but it is quite useful to keep these biases in mind to avoid making too many bad decisions. It is also useful to be mindful that, no matter how aware of these biases you are, you will fall prey to

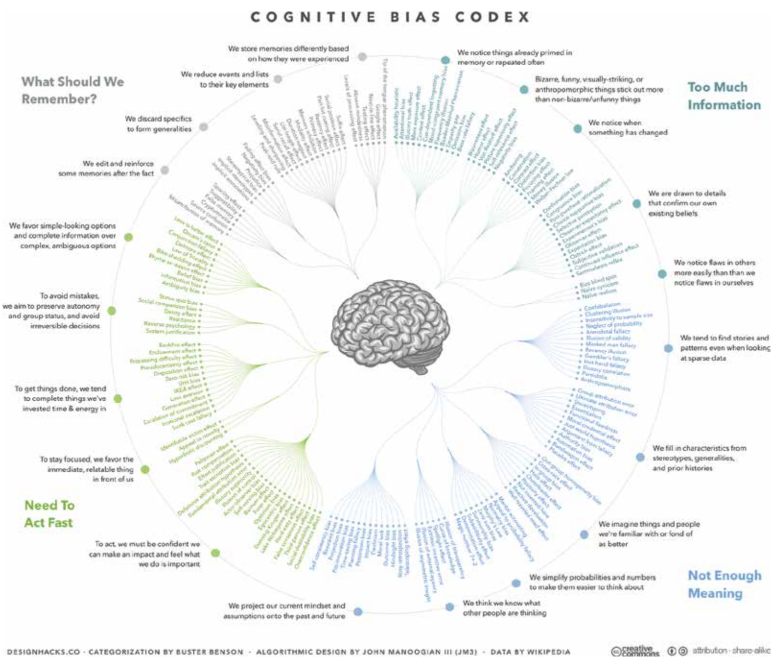

Figure 2.2

Cognitive Bias Codex, designed by John Manoogian III (jm3) and organized by Buster Benson. (From John Manoogian III and Buster Benson, *Cognitive Bias Codex*, Designhacks.co, Chatsworth, California. With permission.)

them from time to time. Try to recognize these traits in yourself and others, even in hindsight. It will make you understand yourself, others, and people's mistakes better—unless you are really attached to the "ostrich effect" and prefer to keep your head buried in the sand. We are all human, with human limitations.

Daniel Kahneman, who received the Nobel Prize in Economic Sciences in 2002, explains in his book, *Thinking, Fast and Slow* (Kahneman 2011), that two modes of thought (System 1 and System 2) influence our mental life. System 1 is fast, instinctive, and emotional thinking. System 2 is much slower, deliberate, and logical, and it involves effortful mental activities such as complex computations. Both systems are active whenever we are awake, and they influence one another. Cognitive biases occur mostly because System 1 operates automatically and is prone to errors of intuitive thoughts and because System 2 might not be aware that these errors are being made. In my opinion, one of the most important cognitive biases to take into account when developing a game is the "curse of knowledge." It is very hard for us to ignore the knowledge we have about something (say, the video game we are developing) and to accurately predict how someone else, who is ignorant about it, will perceive and understand it. This is the main reason why it is critical to regularly test your game's user experience (i.e., UX test) with participants representing your target audience and who do not know anything about it (e.g., playtest, usability test, etc.; see Chapter 14). It is also the reason why game developers, while watching these tests behind one-way mirrors, can become very depressed when they see a participant doing something they find "weird" or "irrational." "Can't he see that he needs to click on the big flashing ability to unleash his powerful ultimate?? I don't understand how he cannot see it, it's so obvious!!" No, it's actually not obvious. It is only obvious to the game developer who already knows where to look, what information is relevant to the current situation, and where to direct attentional resources to be effective. The new player discovering your game does not necessarily know any of this, even if they are expert gamers in the genre. You will have to teach them, which is what we will see in Part II of this book. Now that we have faced brain myths and cognitive biases, let's talk about the cognitive processes that take place in the mind of a person interacting with a product.

2.3 Mental Models and the Player-Centered Approach

Experiencing and enjoying a video game happens in the player's mind, but the experience is crafted by a—sometimes quite considerable—number of developers' minds and is implemented in a system with specific constraints. The difference between what developers originally had in mind, what was implemented given the system's constraints and production constraints, and what players experience in the end can be quite different. This is the reason why considering the gamer's mind and adopting a player-centered approach is key to offering a compelling user experience and to ensuring that what the developers intended is what the players will ultimately experience. In his seminal book, *The Design of Everyday Things*, Donald Norman (2013) explains how designers and end users

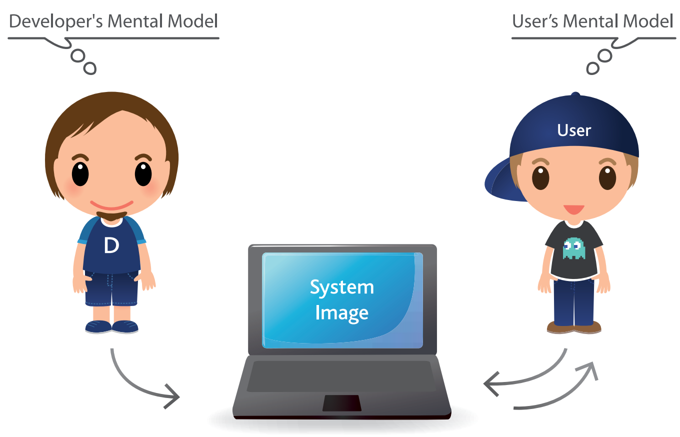

Figure 2.3

Mental models. (Inspired by Norman, D. A. (2013). *The Design of Everyday Things, Revised and Expanded Edition*. New York: Basic Books.)

invoke different mental models, as illustrated in Figure 2.3. A system (such as a PC video game) is designed and implemented based on the developers' mental model of what the system should entail and how it should function. They have to tweak their vision of the game to comply with the limitations of the system (e.g., the rendering features supported by the engine they are using) as well as its requirements (e.g., a virtual reality game must run at a minimum of 90 frames per second to avoid making people simulation sick). Players enter the scene with their prior knowledge and expectations and will develop their own mental model of how *they* think the game works through their interaction with the system image—the part of the system with which they interact and which they perceive. The main objective of user experience and a player-centered approach is to make sure that the user's mental model matches the one developers had intended. To do so, just like developers need to comply with the system limitations and requirements, they also need to comply with the capabilities and limitations of the human brain, and this is why you need to know how the brain works.

2.4 How the Brain Works, in a Nutshell

Pretty much anything you do in life is a learning experience for your brain: watching a movie, finding your bearings, meeting new people, listening to an argument, seeing an advertisement, interacting with a new tool or gadget, and so on. Playing a video game is not any different, and this is why knowing how the brain learns can help developers craft a better experience for their audience. Although learning to play and master a game happens all throughout the game experience, the newest elements are learned during the tutorial—or the onboarding part of the game—so this constitutes one of the biggest hurdles to overcome for players.

First, you have to keep in mind that there is only so much workload the brain can tolerate: The brain consumes about 20% of the body's energy although it only represents 2% of a person's weight. The workload that your game imposes on your audience's brain must therefore be carefully weighed (as much as it can be given that there is no precise measurement for cognitive load) and dedicated to the core experience and challenges you want to offer, not in figuring out, for example, menus, controls, or icons (unless this challenge is by design). Defining your core pillars—what is important for your players to learn and master—and staying focused on them is therefore critical to help you define where you want the player to be challenged. You then need to understand the basics of learning principles to efficiently teach these core elements. The brain is a very complex organ, and it still remains mysterious for the most part. Nonetheless, with the understanding of the learning process explained here, you will be able to determine why players have difficulty grasping or remembering some elements in your game. This will enable you to fix issues efficiently and even to anticipate them. Note that the mind is a product of the brain (and the body); therefore, both are intertwined. Cognitive scientists currently debate the subtleties between mind and brain, but I won't go down that rabbit hole. I consider the brain to be the organ enabling the mind (i.e., mental processes); thus, I will often use one term or the other interchangeably.

Figure 2.4 represents a very simplified chart showing how the brain learns and processes information. Although the brain is not a computer and does not

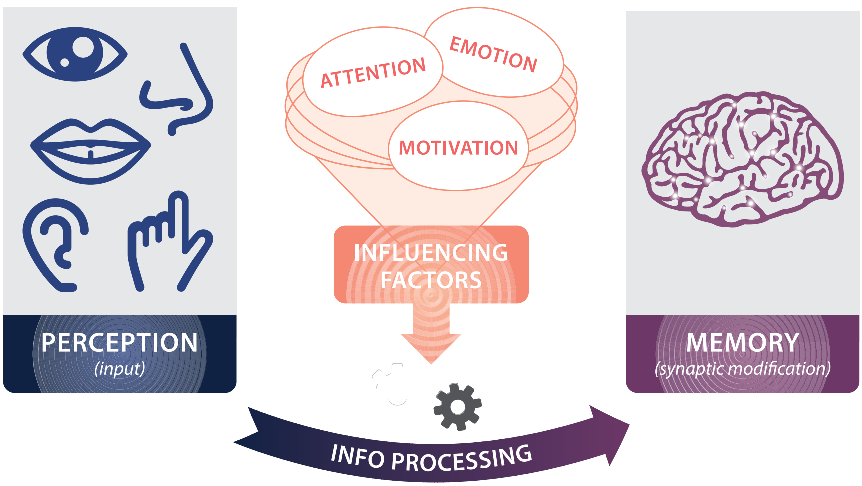

Figure 2.4

A very simplified chart of how the brain learns and processes information.

really have compartments dedicated to a specific function, this chart is a way to boil it down to the essential concepts you need to know as a game developer. Information processing usually starts with the perception of an input and eventually ends with modifications in memory via synaptic modifications in the brain. So, it starts with your senses. We do not have only five senses: sight, hearing, touch, smell, and taste. Rather, we have many other senses, such as those that allow us to perceive a change in temperature, pain, or balance. For example, proprioception is the sense of our body in space that allows us to easily touch our nose with our eyes closed (unless we're inebriated). From a sensory perception to a change in memory, a complex process is happening that is influenced by a myriad of factors. Some of these factors are physiological: You will not learn something as efficiently if you are tired, in pain, or hungry, for example. Your level of attention and the emotions elicited during information processing will also impact the quality of learning, and these are highly dependent on environmental factors (level of noise in the environment, the way the information is organized, and so on). In an effort to boil this down to the essential knowledge you need in order to design video games, the next chapters will focus on perception, attention, memory, motivation, and emotion as if they were independent buckets. However, keep in mind that this is a very simplified version of what is actually going on in the brain. In reality, these cognitive processes are intertwined and do not occur strictly one after the other. And, if I wanted to be perfectly accurate, I should not even say that the brain "processes information" because it does not work like a computer; although getting into this subtlety would probably be overkill for the purposes of this book.