

# Attention and Effort

In the unlikely event of this book being made into a film, System 2 would be a supporting character who believes herself to be the hero. The defining feature of System 2, in this story, is that its operations are effortful, and one of its main characteristics is laziness, a reluctance to invest more effort than is strictly necessary. As a consequence, the thoughts and actions that System 2 believes it has chosen are often guided by the figure at the center of the story, System 1. However, there are vital tasks that only System 2 can perform because they require effort and acts of self-control in which the intuitions and impulses of System 1 are overcome.

## Mental Effort

If you wish to experience your System 2 working at full tilt, the following exercise will do; it should bring you to the limits of your cognitive abilities within 5 seconds. To start, make up several strings of 4 digits, all different, and write each string on an index card. Place a blank card on top of the deck. The task that you will perform is called Add-1. Here is how it goes:

Start beating a steady rhythm (or better yet, set a metronome at 1/sec). Remove the blank card and read the four digits aloud. Wait for two beats, then report a string in which each of the original digits is incremented by 1. If the digits on the card are 5294, the correct response is 6305. Keeping the rhythm is important.

Few people can cope with more than four digits in the Add-1 task, but if you want a harder challenge, please try Add-3.

If you would like to know what your body is doing while your mind is hard at work, set up two piles of books on a sturdy table, place a video camera on one and lean your chin on the other, get the video going, and stare at the camera lens while you work on Add-1 or Add-3 exercises. Later, you will find in the changing size of your pupils a faithful record of how hard you worked.

I have a long personal history with the Add-1 task. Early in my career I spent a year at the University of Michigan, as a visitor in a laboratory that studied hypnosis. Casting about for a useful topic of research, I found an article in *Scientific American* in which the psychologist Eckhard Hess described the pupil of the eye as a window to the soul. I reread it recently

and again found it inspiring. It begins with Hess reporting that his wife had noticed his pupils widening as he watched beautiful nature pictures, and it ends with two striking pictures of the same good-looking woman, who somehow appears much more attractive in one than in the other. There is only one difference: the pupils of the eyes appear dilated in the attractive picture and constricted in the other. Hess also wrote of belladonna, a pupil-dilating substance that was used as a cosmetic, and of bazaar shoppers who wear dark glasses in order to hide their level of interest from merchants.

One of Hess's findings especially captured my attention. He had noticed that the pupils are sensitive indicators of mental effort—they dilate substantially when people multiply two-digit numbers, and they dilate more if the problems are hard than if they are easy. His observations indicated that the response to mental effort is distinct from emotional arousal. Hess's work did not have much to do with hypnosis, but I concluded that the idea of a visible indication of mental effort had promise as a research topic. A graduate student in the lab, Jackson Beatty, shared my enthusiasm and we got to work.

Beatty and I developed a setup similar to an optician's examination room, in which the experimental participant leaned her head on a chin-and-forehead rest and stared at a camera while listening to prerecorded information and answering questions on the recorded beats of a metronome. The beats triggered an infrared flash every second, causing a picture to be taken. At the end of each experimental session, we would rush to have the film developed, project the images of the pupil on a screen, and go to work with a ruler. The method was a perfect fit for young and impatient researchers: we knew our results almost immediately, and they always told a clear story.

Beatty and I focused on paced tasks, such as Add-1, in which we knew precisely what was on the subject's mind at any time. We recorded strings of digits on beats of the metronome and instructed the subject to repeat or transform the digits one indigit only one, maintaining the same rhythm. We soon discovered that the size of the pupil varied second by second, reflecting the changing demands of the task. The shape of the response was an inverted V. As you experienced it if you tried Add-1 or Add-3, effort builds up with every added digit that you hear, reaches an almost intolerable peak as you rush to produce a transformed string during and immediately after the pause, and relaxes gradually as you "unload" your short-term memory. The pupil data corresponded precisely to subjective experience: longer strings reliably caused larger dilations, the transformation task compounded the effort, and the peak of pupil size coincided with maximum effort. Add-1 with four digits caused a larger

dilation than the task of holding seven digits for immediate recall. Add-3, which is much more difficult, is the most demanding that I ever observed. In the first 5 seconds, the pupil dilates by about 50% of its original area and heart rate increases by about 7 beats per minute. This is as hard as people can work—they give up if more is asked of them. When we exposed our subjects to more digits than they could remember, their pupils stopped dilating or actually shrank.

We worked for some months in a spacious basement suite in which we had set up a closed-circuit system that projected an image of the subject's pupil on a screen in the corridor; we also could hear what was happening in the laboratory. The diameter of the projected pupil was about a foot; watching it dilate and contract when the participant was at work was a fascinating sight, quite an attraction for visitors in our lab. We amused ourselves and impressed our guests by our ability to divine when the participant gave up on a task. During a mental multiplication, the pupil normally dilated to a large size within a few seconds and stayed large as long as the individual kept working on the problem; it contracted immediately when she found a solution or gave up. As we watched from the corridor, we would sometimes surprise both the owner of the pupil and our guests by asking, "Why did you stop working just now?" The answer from inside the lab was often, "How did you know?" to which we would reply, "We have a window to your soul."

The casual observations we made from the corridor were sometimes as informative as the formal experiments. I made a significant discovery as I was idly watching a woman's pupil during a break between two tasks. She had kept her position on the chin rest, so I could see the image of her eye while she engaged in routine conversation with the experimenter. I was surprised to see that the pupil remained small and did not noticeably dilate as she talked and listened. Unlike the tasks that we were studying, the mundane conversation apparently demanded little or no effort—no more than retaining two or three digits. This was a eureka moment: I realized that the tasks we had chosen for study were exceptionally effortful. An image came to mind: mental life—today I would speak of the life of System 2—is normally conducted at the pace of a comfortable walk, sometimes interrupted by episodes of jogging and on rare occasions by a frantic sprint. The Add-1 and Add-3 exercises are sprints, and casual chatting is a stroll.

We found that people, when engaged in a mental sprint, may become effectively blind. The authors of *The Invisible Gorilla* had made the gorilla "invisible" by keeping the observers intensely busy counting passes. We reported a rather less dramatic example of blindness during Add-1. Our

subjects were exposed to a series of rapidly flashing letters while they worked. They were told to give the task complete priority, but they were also asked to report, at the end of the digit task, whether the letter *K* had appeared at any time during the trial. The main finding was that the ability to detect and report the target letter changed in the course of the 10 seconds of the exercise. The observers almost never missed a *K* that was shown at the beginning or near the end of the Add-1 task but they missed the target almost half the time when mental effort was at its peak, although we had pictures of their wide-open eye staring straight at it. Failures of detection followed the same inverted-V pattern as the dilating pupil. The similarity was reassuring: the pupil was a good measure of the physical arousal that accompanies mental effort, and we could go ahead and use it to understand how the mind works.

Much like the electricity meter outside your house or apartment, the pupils offer an index of the current rate at which mental energy is used. The analogy goes deep. Your use of electricity depends on what you choose to do, whether to light a room or toast a piece of bread. When you turn on a bulb or a toaster, it draws the energy it needs but no more. Similarly, we decide what to do, but we have limited control over the effort of doing it. Suppose you are shown four digits, say, 9462, and told that your life depends on holding them in memory for 10 seconds. However much you want to live, you cannot exert as much effort in this task as you would be forced to invest to complete an Add-3 transformation on the same digits.

System 2 and the electrical circuits in your home both have limited capacity, but they respond differently to threatened overload. A breaker trips when the demand for current is excessive, causing all devices on that circuit to lose power at once. In contrast, the response to mental overload is selective and precise: System 2 protects the most important activity, so it receives the attention it needs; "spare capacity" is allocated second by second to other tasks. In our version of the gorilla experiment, we instructed the participants to assign priority to the digit task. We know that they followed that instruction, because the timing of the visual target had no effect on the main task. If the critical letter was presented at a time of high demand, the subjects simply did not see it. When the transformation task was less demanding, detection performance was better.

The sophisticated allocation of attention has been honed by a long evolutionary history. Orienting and responding quickly to the gravest threats or most promising opportunities improved the chance of survival, and this capability is certainly not restricted to humans. Even in modern humans, System 1 takes over in emergencies and assigns total priority to self-protective actions. Imagine yourself at the wheel of a car that unexpectedly

skids on a large oil slick. You will find that you have responded to the threat before you became fully conscious of it.

Beatty and I worked together for only a year, but our collaboration had a large effect on our subsequent careers. He eventually became the leading authority on "cognitive pupillometry," and I wrote a book titled *Attention and Effort*, which was based in large part on what we learned together and on follow-up research I did at Harvard the following year. We learned a great deal about the working mind—which I now think of as System 2—from measuring pupils in a wide variety of tasks.

As you become skilled in a task, its demand for energy diminishes. Studies of the brain have shown that the pattern of activity associated with an action changes as skill increases, with fewer brain regions involved. Talent has similar effects. Highly intelligent individuals need less effort to solve the same problems, as indicated by both pupil size and brain activity. A general "law of least effort" applies to cognitive as well as physical exertion. The law asserts that if there are several ways of achieving the same goal, people will eventually gravitate to the least demanding course of action. In the economy of action, effort is a cost, and the acquisition of skill is driven by the balance of benefits and costs. Laziness is built deep into our nature.

The tasks that we studied varied considerably in their effects on the pupil. At baseline, our subjects were awake, aware, and ready to engage in a task—probably at a higher level of arousal and cognitive readiness than usual. Holding one or two digits in memory or learning to associate a word with a digit (3 = door) produced reliable effects on momentary arousal above that baseline, but the effects were minuscule, only 5% of the increase in pupil diameter associated with Add-3. A task that required discriminating between the pitch of two tones yielded significantly larger dilations. Recent research has shown that inhibiting the tendency to read distracting words (as in figure 2 of the preceding chapter) also induces moderate effort. Tests of short-term memory for six or seven digits were more effortful. As you can experience, the request to retrieve and say aloud your phone number or your spouse's birthday also requires a brief but significant effort, because the entire string must be held in memory as a response is organized. Mental multiplication of two-digit numbers and the Add-3 task are near the limit of what most people can do.

What makes some cognitive operations more demanding and effortful than others? What outcomes must we purchase in the currency of attention? What can System 2 do that System 1 cannot? We now have tentative answers to these questions.

Effort is required to maintain simultaneously in memory several ideas

that require separate actions, or that need to be combined according to a rule—rehearsing your shopping list as you enter the supermarket, choosing between the fish and the veal at a restaurant, or combining a surprising result from a survey with the information that the sample was small, for example. System 2 is the only one that can follow rules, compare objects on several attributes, and make deliberate choices between options. The automatic System 1 does not have these capabilities. System 1 detects simple relations (“they are all alike,” “the son is much taller than the father”) and excels at integrating information about one thing, but it does not deal with multiple distinct topics at once, nor is it adept at using purely statistical information. System 1 will detect that a person described as “a meek and tidy soul, with a need for order and structure, and a passion for detail” resembles a caricature librarian, but combining this intuition with knowledge about the small number of librarians is a task that only System 2 can perform—if System 2 knows how to do so, which is true of few people.

A crucial capability of System 2 is the adoption of “task sets”: it can program memory to obey an instruction that overrides habitual responses. Consider the following: Count all occurrences of the letter *f* in this page. This is not a task you have ever performed before and it will not come naturally to you, but your System 2 can take it on. It will be effortful to set yourself up for this exercise, and effortful to carry it out, though you will surely improve with practice. Psychologists speak of “executive control” to describe the adoption and termination of task sets, and neuroscientists have identified the main regions of the brain that serve the executive function. One of these regions is involved whenever a conflict must be resolved. Another is the prefrontal area of the brain, a region that is substantially more developed in humans than in other primates, and is involved in operations that we associate with intelligence.

Now suppose that at the end of the page you get another instruction: count all the commas in the next page. This will be harder, because you will have to overcome the newly acquired tendency to focus attention on the letter *f*. One of the significant discoveries of cognitive psychologists in recent decades is that switching from one task to another is effortful, especially under time pressure. The need for rapid switching is one of the reasons that Add-3 and mental multiplication are so difficult. To perform the Add-3 task, you must hold several digits in your working memory at the same time, associating each with a particular operation: some digits are in the queue to be transformed, one is in the process of transformation, and others, already transformed, are retained for reporting. Modern tests of working memory require the individual to switch repeatedly between two

demanding tasks, retaining the results of one operation while performing the other. People who do well on these tests tend to do well on tests of general intelligence. However, the ability to control attention is not simply a measure of intelligence; measures of efficiency in the control of attention predict performance of air traffic controllers and of Israeli Air Force pilots beyond the effects of intelligence.

Time pressure is another driver of effort. As you carried out the Add-3 exercise, the rush was imposed in part by the metronome and in part by the load on memory. Like a juggler with several balls in the air, you cannot afford to slow down; the rate at which material decays in memory forces the pace, driving you to refresh and rehearse information before it is lost. Any task that requires you to keep several ideas in mind at the same time has the same hurried character. Unless you have the good fortune of a capacious working memory, you may be forced to work uncomfortably hard. The most effortful forms of slow thinking are those that require you to think fast.

You surely observed as you performed Add-3 how unusual it is for your mind to work so hard. Even if you think for a living, few of the mental tasks in which you engage in the course of a working day are as demanding as Add-3, or even as demanding as storing six digits for immediate recall. We normally avoid mental overload by dividing our tasks into multiple easy steps, committing intermediate results to long-term memory or to paper rather than to an easily overloaded working memory. We cover long distances by taking our time and conduct our mental lives by the law of least effort.

## **Speaking of Attention and Effort**

"I won't try to solve this while driving. This is a pupil-dilating task. It requires mental effort!"

"The law of least effort is operating here. He will think as little as possible."

"She did not forget about the meeting. She was completely focused on something else when the meeting was set and she just didn't hear you."

“What came quickly to my mind was an intuition from System 1. I’ll have to start over and search my memory deliberately.”