Memory, which feels monolithic, is a bestiary of many processes.

In associative conditioning, the organism connects two simultaneous or nearly simultaneous events to each other, such that one predicts the other. Some forms of Pavlovian conditioning require selective attention and awareness of the relationship between the conditioned and the unconditioned stimuli. Given the ease with which mice can learn, these forms of conditioning can be developed into an operational test for murine awareness.

Procedural memory contains instructions, such as how to ride a bike, tie shoelaces, or execute a sequence of climbing moves. Episodic memory encodes autobiographical events, while semantic memory deals with more abstract knowledge. Both are forms of declarative memory. In severe cases of amnesia, people are not only unable to form new declarative memories but also lose access to previously stored ones. These unfortunate individuals suffer from bilateral destruction of the hippocampus and associated medial temporal lobe structures, yet are certainly conscious. They conclusively demonstrate that consciousness does not depend on long-term episodic memories.

Shorter forms of storage rely on active neuronal circuits. Best characterized is working memory, which is quite limited in how much it can store. It does so in an abstract, categorical fashion. Unless continuously rehearsed, working memory decays within a minute. It is critical for all those daily tasks where data is briefly retained and manipulated.

In a well-functioning brain, working memory goes hand-in-hand with consciousness. Any organism with working memory capabilities is likely to be conscious, making the presence of working memory a litmus test for consciousness in animals, babies, or patients that can't talk about their experiences. The opposite, however, may not be true. I suspect that if a man were to be stripped of his working memory, he would remain conscious. He could still feel the world, even though he might not be able to talk about it afterward.

Iconic memory, on the other hand—a fleeting form of visual information storage that lasts for less than one second—is probably necessary for visual perception. Its neuronal substrate is the afterglow left by the waves of spikes sweeping up the visual hierarchy, amplified by local and more global feedback loops. The function of iconic memory may be to assure that even brief images last sufficiently long to trigger the NCC.

Retaining information over a few seconds, as in trace conditioning or working memory, is a common feature of many processes closely linked to consciousness. This idea is elaborated into a practical test for consciousness in Section 13.6. Before I come to that, however, let me tell you about the zombie within.

What You Can Do Without Being Conscious: The Zombie Within

At this point, apart from a gnawing desire to be close to Belqassim all the time, it would have been hard for her to know what she did feel. It was so long since she had canalized her thoughts by speaking aloud, and she had grown accustomed to acting without the consciousness of being in the act. She did only the things she found herself already doing.

From The Sheltering Sky by Paul Bowles

Zombies could be living among us. Or so claim some philosophers. These fictitious creatures are devoid of any subjective feelings, yet are endowed with behaviors identical to their normal, conscious counterparts. It does not feel like anything to be a zombie. They were invented by philosophers in their carefree way to illustrate the paradoxical nature of consciousness. Some argue that the logical possibility of their existence implies that consciousness does not follow from the natural laws of the universe, that it is an epiphenomenon. From this viewpoint, whether or not people feel makes no difference to themselves, to their offspring, and to the world at large.1

To Francis and me, this point of view seems sterile. We are interested in the real world, not in a logically possible never-never land where zombies roam. And, in the real world, evolution gave rise to organisms with subjective feelings. These convey significant survival advantages, because consciousness goes hand-in-hand with the ability to plan, to reflect upon many possible courses of action, and to choose one. I will expand upon this in Chapter 14.

What is of great interest is the observation that much of what goes on inside my head escapes me. As I grow older, reflecting upon a lifetime of experience,
it dawns upon me that large parts of my life lie beyond the pale of consciousness. I do things—complicated actions like driving, talking, going to the gym, cooking—automatically, without thinking about them.

Try to introspect the next time you talk. You will hear well-formed sentences come tumbling out of your mouth, but without any knowledge of what entity formed them with the appropriate syntax. Your brain takes care of that quite well without any conscious effort on your part. You might remind yourself to mention this anecdote or that observation, but the conscious "you" does not generate the words or put them in the right order.

None of this is new. The submental, the unconscious—defined by exclusion as everything going on in the brain insufficient for conscious feelings, sensations, or memories—has been a scholarly topic since the latter part of the 19th century. Friedrich Nietzsche was the first major Western thinker to explore the darker recesses of humanity's unconscious desires to dominate others and acquire power over them, often disguised as compassion. Within the medical-literary tradition, Freud spent a lifetime arguing for the existence of repressed desires and thoughts and their uncanny ability to influence behavior in hidden ways.

Science has provided credible evidence for an entire menagerie of specialized sensory-motor processes, what I call zombie agents, that carry out routine missions in the absence of any direct conscious sensation or control. You can become conscious of the action of a zombie agent, but usually only after the fact, through internal or external feedback. Unlike the philosopher's or the veterinarian, though, zombie agents operate continuously in all of us.

These agents have one unfortunate practical consequence: The mere existence of some seemingly complex behavior does not necessarily imply that the subject is conscious. To the dismay of pet owners or new parents alike, the friendly dog wagging her tail or the baby smiling ever so cutely might be doing so automatically. Additional criteria must be devised to detect consciousness.

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3. Ellenberger (1970) provides a historical perspective on the non- and unconscious. The rigorous study of unconscious sensory-motor behaviors is fraught with methodological difficulties. It is not easy to disentangle the rapid and automatic initiation of an action from a retarded one but conscious signal triggered by the command to act or by the executed action itself. Another complication arises from the need for multiple trials, necessary to collect sufficient statistics. The repetition of the task can provide evidence of the subject—over time—that can be more conscious of some aspect of the behavior. For reviews and relevant experiments, see Cheesman and Merikle (1986); Holender (1986); Merikle (1992); Kolb and Braun (1995); Berns, Cheesman, and Merikle (1996); Merikle, Smilie, and Eastwood (2001); Denrebrock and Cleeremans (2001); and Curran (2001).

4. In general, I avoid using the term "unconscious" because of its Freudian overtones, preferring the more neutral "nonconscious" to refer to operations or computations not sufficient for the phenomenal content.
Balancing the Body

Other nonconscious agents control head, limb, and body posture. As you weave your way through crowds of shoppers on the sidewalk, your trunk, legs, and arms continuously adjust themselves so that you remain upright, and avoid bumping into anybody. You don’t give a thought to these actions that require split-second timing and a marvelous merging of muscle and nerve, something no machine has come close to achieving.

In one ingenious experiment, psychologists had people stand inside a fake room, whose polystyrene walls were suspended from the ceiling within a larger room. As the foam walls gently rocked back and forth by a few millimeters, subjects adjusted their posture by swaying back and forth in tune. Most remained unaware of the motion of the room or of the compensatory adjustment of their body.

The networks mediating balance and body posture receive continuously updated information from many modalities, not just vision. The inner ears supply head rotation and linear acceleration, while myriad motion, position, and pressure sensors in the skin, muscles, and joints monitor the position of the body in space. All of this information is at the service of highly coordinated yet nonconscious zombie agents that prevent you from crashing into the approaching cyclist and that balance you when your friend unexpectedly slaps you on your back.\(^5\)

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5Lee and Lishman (1975).
6I recommend reading the inspiring case-history of a 19-year-old who suddenly lost all body sensation below the neck (Cole, 1995). In the absence of any proprioceptive feedback from his body, the patient gradually learned, with amazing tenacity, to consciously control his limbs by sight. The book brings home how utterly daily life depends on nonconscious processing.

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Estimating the Steepness of Hills

When driving in the mountains, have you ever wondered about the “obvious” discrepancy between the slope indicated on the road sign and your feeling that the incline was much steeper? The psychologist Dennis Proffitt at the University of Virginia at Charlottesville confirmed this informal observation. It is but one striking example of a dissociation between perception and action.\(^7\)

Proffitt and his assistants stood at the bases of hills and queried 300 passing students about the slope using verbal, visual, and manual measures. For the visual judgment, subjects had to set a disk mounted behind a concealed protractor to the angle that they thought best matched the inclination of the clearly visible hill. In the manual mode, volunteers adjusted a tilt board with a flat palm rest mounted on a tripod. To avoid “contamination” from vision, they were prevented from looking at their hand.

Subjects badly overestimated the slopes of these hills when judging verbally or visually, but were within the right ballpark when inferring the steepness using their hand (Figure 12.2).

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7Proffitt et al. (1995).
Remarkably, the mismatch between the perceived slope of a hill and visually guided actions, such as hand or foot placement, depends on the physiological state of the individual. Both verbal and visual overestimates of hill steepness increased by more than a third following an exhausting foot race, while the blind hand estimate was unaffected. If you’re fatigued, therefore, hills do look steeper than if you’re rested.8 What you consciously see is not the same as what guides your actions.

Night Walking

I spent part of the summer of 1994 at the Santa Fe Institute for Complexity in New Mexico. Sandra Blakeslee, a science journalist living in the area, convinced me to join a nightly tour conducted by Nelson Zink and Stephen Parks, psychotherapists and writers operating out of Taos. I went along for a rather tantaizing experience that may be another example of an automatic visuo-motor behavior divorced from conscious perception.

We assembled on a floor of a canyon wall outside town at night. The moonless sky was clear, with hundreds of stars shining down. Thus, visibility was low, but not zero. We wore baseball caps with a wire sticking straight ahead and a phosphorescent sphere attached to the end. Charged up by a flashlight, the sphere would faintly glow for minutes. The trick was to walk erect in the dark while looking at the sphere, suspended below the cap, and to keep fixating it despite the urge to inspect the ground ahead. At first, I gingerly moved forward on the sandy and rocky floor, exploring with my feet before committing the full weight of my body. After a surprising short time, however, I became more confident and walked at a comparatively brisk pace over the highly uneven ground, all the while staring at the sphere. Eventually, the sphere became superfluous and fixating the distant horizon or a star was sufficient to prevent central vision from aiding in the placement of the feet.

One explanation for this night walking is that information gleaned at some distance is stored implicitly and guides the placement of the feet once that location is reached. This would be a considerable feat in these canyons full of sandy hills, holes, and dried river beds.9

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8 A similar effect was found when subjects wore a heavy backpack, or were of low physical fitness, elderly, or in declining health (Bhalla and Proffitt, 1999). Proffitt argues that the variable relationship between actual and perceived steepness reflects the behavioral potential of the organism. The subjective slant percept corresponds to your ability to ascend hills. This is hard work and should not be undertaken lightly. It becomes even harder if you are tired, frail, or carrying a heavy load.

9I confirmed the need for peripheral vision since glasses that covered everything but the central part of the visual field made navigation impossible.

10 Receptive fields of the ventral, vision-for-perception pathway are centered on or around the fovea.


12 Wong and Mack (1981); Abrams and Landgraf (1990); and, in particular, the study by Friedman, Peery, and Anand (1997).
Because on-line agents help the organism to safely navigate the world, they need access to the true position of a target relative to the body. Perception, on the other hand, must recognize things and label them as "spoiled banana," "blushing face," and so on. These objects can be far away or close by, and must be recognized in the full light of the midday sun or at dusk, so that object perception must be invariant to distance, ambient light, exact location on the retina, and so on. As a result, the spatial location of what you see consciously is not as precise as the information accessible to your nonconscious agent planning the next move.

This strategy makes perfect sense from a computational point of view. The neuronal algorithms needed to reach out and grab a tool (vision-for-action) operate within a frame of reference and have invariances different from the operations that identify the object as a hammer (vision-for-perception).

In the normal course of daily events, zombie agents are tightly enmeshed with the networks mediating perception. What you perceive, learn, or remember is an interweaving of nonconscious and conscious processes and separating their contributions is no easy matter. By investigating the seams where vision-for-perception and vision-for-action come apart, Milner and Goodale probe the two in relative isolation.

Perception must recognize objects for what they are, no matter where they are. Conversely, the motor system must know about the exact spatial relationship of some to-be-manipulated object relative to the organism. In keeping with this view, Milner and Goodale argue that size constancy illusion—the fact that an object looks to have the same size no matter whether it is far away or close by—only applies to vision-for-perception, not to vision-for-action, whose job is to look at, point to, or pick up objects. This requires precise information about the object’s size, location, weight, and shape. These seduc-

tive ideas have begun to be tested, but so far no firm conclusions have been reached. Some dissociations between vision-for-action and perception have been uncovered—witness the previous section on slope estimation—but have failed to materialize elsewhere.

The hypothesis of a collection of specialized visuo-motor zombie agents, complemented by a more general purpose, multi-faceted, conscious vision module, is an attractive one. It nicely dovetails with our proposal, laid out in Chapter 14, that the function of consciousness is to deal with all those situations that require a novel, nonstereotyped response.

12.3 | YOUR ZOMBIE ACTS FASTER THAN YOU SEE

One of the cardinal advantages of zombie agents is that their specialized nature allows them to respond more rapidly than the general purpose perceptual system. You grab for the pencil before you actually see it roll off the table or you move your hand away from the hot burner before you feel its heat.

This last point is important, for it belies the notion that you jerk your hand away because you consciously feel pain. The withdrawal of a limb following an irritating or noxious stimulus is a spinal reflex; it does not require the brain. Indeed, decapitated animals as well as paraplegics whose lower spinal cord is disconnected from the brain, have such withdrawal reflexes. Consciousness does not have to be involved (keep this point in mind when I discuss the function of consciousness in Chapter 14).16

Marc Jeannerod from the Institut des Sciences Cognitives in Bron, France, is one of the world’s leading experts in the neuropsychology of action. In one noteworthy experiment,17 Jeannerod and his colleagues estimated the delay

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14 Geometry dictates that linear size is inversely proportional to distance. Yet somebody five meters away doesn’t look twice the size they were 10 meters away. Aglioti, DeSouza, and Goodale (1995) provide evidence for size constancy operating in the perceptual but not in the visuo-motor domain, while Franz et al. (2000) found no such dissociation (see also Yamagishi, Anderson, and Ashida, 2001; Carey, 2001; and Milner and Hyde, 2003).

15 In an experiment on spatial navigation, people judged the distance (between one or five meters) to a clearly visible target. This estimate was compared to dead reckoning, when subjects walked with their eyes closed to the (presumed) location of the target. Both measures consistently underestimated the distance to nearby points and underestimated it for more distant locations (Philbeck and Loomis, 1997). Since both deviated to the same extent from the true physical distance, both measures make use of the same information, unlike the slope estimate discussed in the previous section.

16 For example, if a noxious stimulus is applied to the back of a headless frog, the appropriate limb tries to scratch at it. The remarkable sensory-motor abilities of decapitated or decerebrated animals were at the core of a debate in the second half of the 19th century over the extent to which consciousness was associated with the spinal cord (Feiring, 1970).

between a rapid manual response and subjective awareness. Three dowels were placed in front of an observer with her hand resting on the table. Suddenly, the central dowel was lit from below and she had to reach out and grasp it as rapidly as she could. On occasion, the light was shifted to either the left or right dowel immediately as the hand started to move, and this one became the new target. As soon as the subject saw the new target light up, she had to shout.

On average, 315 msec would go by between the onset of the motor response and the vocalization. Indeed, in some cases, the subject had already lifted the second dowel before she realized that it was the new target—that is, action preceded awareness. Even when a generous 50 msec was accorded to the lag between the onset of muscle contraction of the speech articulators and the beginning of the shout, this still left a quarter of a second between the grasping behavior and the conscious percept that led to the shout. This delay is the price that must be paid for consciousness.

To put this into perspective, consider a track athlete. Assuming, with a grain of salt, that the 250-msec delay also applies to the auditory system, then the sprinter is already out of the starting block by the time he consciously hears the starting gun go off! Similarly, a baseball player facing a pitched ball approaching at 90 mph must begin to swing his bat before he is conscious of his decision to try to hit the ball or let it pass.

12.4 | CAN ZOMBIES SMELL?

Zombie agents are not limited to the visual domain. They are found in all modalities. One profitable sense to explore is smell. Although contemporary culture strongly frowns upon body odors—a sentiment that has given birth to endless hygienic products that seek to camouflage them—we do live in a redundant world, whether we are aware of it or not. Indeed, it has long been surmised that many sexual, appetitive, reproductive, and social behaviors are triggered by subliminal olfactory cues. This theory has been difficult to establish rigorously.

Examples where smell-based decisions have been studied extend from the banal, such as choosing a seat in a cinema, to the essential, such as choosing a sexual partner. The best-publicized example is the synchronization of menstrual cycles among women who live or work closely together (as in college dormitories or military barracks). In one well-designed study, Martha McClintock at the University of Chicago applied odorless compounds from the armpits of women to the upper lips of other females. The menstrual cycle of the recipient was shortened or lengthened, depending on the phase of the donor.19

Such effects could be mediated by pheromones, volatile compounds secreted by one individual that alter the physiology or behavior of another individual. Some animals can respond to single molecules of pheromones.20 In the case of humans, armpit secretions of men contain a testosterone derivative, while women exude a compound that resembles estrogen. Both airborne substances induce gender-specific physiological changes in deep neural structures.21

How might such unconscious airborne signals be mediated? One culprit may be the vomeronasal organ. It is not widely appreciated that mammals possess not one but two senses of smell. The primary olfactory organ originates in the main epithelium of the nose and projects to the olfactory bulb and from there to the olfactory cortex. This organ is a broadly tuned, all-purpose system. A second module starts off in the vomeronasal organ at the base of the nasal cavity. From there, axons go to the accessory olfactory bulb and onward to the amygdala. The vomeronasal organ transduces pheromones and has been linked to gender-specific communication.22

Enough is known about mouse olfactory receptor molecules that their expression can be blocked in one but not the other organ, making it possible to study the molecular and neuronal correlates of genetically programmed sexual or reproductive behaviors.23

In most people, the vomeronasal system, sometimes referred to as Jacobson’s organ, may be vestigial—nonfunctional. Its job may have been taken over by the primary olfactory pathway. Another distinct possibility is that only a subset of adults express the relevant receptors. A vigorous research program could identify the individuals susceptible to ‘odorless’ smells for further genetic and physiological screening, to contrast the neural substrate of unconscious and conscious olfactory processing.

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20 Pasteaga and Dulac (2000).

21 The testosterone-derived pheromone triggers a response in the hypothalamus of women but not of men, while the estrogen-related substance excites the hypothalamus of men but not of women (Savic et al., 2001, and Savic, 2002). Even when the odor could not be detected by the subject, some brain activity persisted (Sobel et al., 1999).

22 Johnston (1998) and Keverne (1999) review the scholarly literature, while Watson (2001) provides a popular account. Holy, Dulac, and Meister (2000) discovered that single vomeronasal neurons in the mouse are capable of distinguishing female from male urine.

23 Researchers can now breed mice whose vomeronasal organ is knocked out. These transgenic animals lack male-male aggression. Instead they initiate courtship behaviors toward both males and females (Stowers et al., 2002).
12.5 | RECAPITULATION

This chapter reviewed the ample evidence for zombie agents—highly specialized, sensory-motor agents that work quite well without giving rise to phenomenal sensations. The hallmarks of a zombie agent are (1) rapid, reflex-like processing, (2) a narrow but specific input domain, (3) a specific behavior, and (4) the lack of access to working memory.

In the visual domain, Milner and Goodale argue for two distinct processing strategies, vision-for-action and vision-for-perception, implemented by networks within the dorsal and the ventral pathways, respectively. Because the job of visuo-motor agents is to grasp or point at things, they need to encode the actual distance between the body and these objects, their size, and other metric measures. The vision-for-perception mode mediates conscious vision. It must recognize things, no matter their size, orientation, or location. This explains why zombie agents access more veridical information about spatial relationships in the world than perception can. That is, while you may not see what is really out there, your motor system does. Prominent examples of such dissociations include tracking targets with the eyes, adjusting body posture, estimating the steepness of hills, and night walking.

Zombie agents control your eyes, hands, feet, and posture, and rapidly transduce sensory input into stereotypical motor output. They might even trigger aggressive or sexual behaviors when getting a whiff of the right stuff. All, however, bypass consciousness. This is the zombie you.

So far, I have said nothing about the differences between zombie and conscious processing modes at the neuronal level. The forward propagating netwave triggered by a brief sensory input may be too transient to be sufficient for the NCC, but can mediate zombie behaviors. What is needed for conscious perception is enough time for feedback activity from frontal areas to build up stable coalitions. I will expand on this theme in Section 15.3.

Dissociations between conscious and nonconscious behaviors can be more prominent in sickness. This is the topic of the next chapter.

13.1 | VISUAL AGNOSIA

Pure agnosia, a relatively rare condition, is defined as a failure of recognition that cannot be attributed to elementary sensory defects (e.g., retinal deficits), mental or linguistic deterioration, or attentional disturbances. It is often limited to one sensory modality. Typically, a visual agnosia patient can't recognize a set of keys on a chain dangling in front of her. If she argues that she can't

CHAPTER THIRTEEN

Agnosia, Blindsight, Epilepsy, and Sleep Walking: Clinical Evidence for Zombies

And as for sickness: are we not almost tempted to ask whether we could get along without it?

From The Gay Science by Friedrich Nietzsche

Morbidity often accentuates or brings out traits that are barely apparent in good health. Historically, the clinic has been one of the most fecund sources of insight about the brain. The vagaries of nature give rise to anoxia, strokes, tumors, or other pathological aberrations that, if limited in their scope and correctly interpreted, can illuminate and guide my quest.

In the intact brain, zombie behaviors are so tightly interwoven with conscious ones that it is difficult to isolate them. For, even if the response was generated automatically, awareness may follow within the blink of an eye. Let me now turn to four clinical syndromes that better reveal the actions of zombie agents.