

WATCHING MINDS INTERACT

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To anyone who hasn't yet met one, the members of *Homo sapiens* must surely seem like the species least likely to dominate the planet. Compared with most other terrestrial mammals, humans are a pretty scrawny bunch. We don't come equipped with sharp claws or fangs; we're not particularly swift or strong; we don't have special physical adaptations that would allow us to fly, poison potential predators, or cloak ourselves in camouflage. To a hungry lion, this hairless, frail ape, standing upright on the savannah, must have been the least troublesome of afternoon snacks.

And yet, despite these obvious physical shortcomings, humans are Earth's undisputed masters—at least for the time being. We have co-opted the life history of hundreds of plant and animal species through domestication, and we are responsible for the extinction of hundreds of others. Our technology continues to transform the planet itself—the land, the sea, the

atmosphere. Our command of Earth is so nearly complete that humans maintain a presence in places that harbor few or no other organisms, such as the South Pole and low-Earth orbit.

How has our species of fragile-seeming primates managed to subjugate the rest of Earth's inhabitants? The answer, of course, is that natural selection has equipped us with an adaptation more fearsome than teeth or claws: the human brain.

Composed of 100 billion neurons, each communicating with an average of 1,000 other neurons dozens of times per second, the adult human brain is the most complex object in the known universe, a biological supercomputer with a processing capacity that dwarfs the most sophisticated silicon-chip computers we are likely to see in our lifetimes. Thanks to the tremendous computational power of our brains, humans have been able to transcend the need for the kinds of weapons in which many other organisms invest.

And yet, how exactly do our prodigious brains provide an advantage to our species? Unlike claws and wings and venomous fangs, our brains have no direct interaction with the environment around us. (It's safe to say that things have gone horribly wrong if you suddenly find your brain in contact with the objects around you.) Instead, our brains are the prima donnas of the biological world, sequestered behind a bony fortification half an inch thick, greedily devouring more than 20 percent of the body's energy. Since brains do not directly effect change in the world around them, how did they give us an adaptive leg up on other organisms?

Unlike most other adaptations, the brain requires a system to translate the only physical actions of which it is capable—the electrochemical firing of its neurons—into the physical

actions, such as speech and toolmaking, that have enabled us to dominate our surroundings. In the twenty-first century, most of us are familiar with an analogous translational system: the operating systems and other software that translate the physical actions of a computer processor (the electrical switching of binary diodes) into the physical actions that make computers so useful—for example, the arrangement of colored points on a monitor into meaningful images, such as words or pictures. The particular system of translation used by the human brain is known as the *mind*, which may be defined as the algorithms by which one set of physical actions is mapped onto a different set of physical actions by the brain.

The branch of science that attempts to describe these algorithms is psychology, whose ultimate goal is the assembling of a full catalog of the subroutines and other processing steps with which human beings translate physical information from the environment (photons of light, vibrating waves of air) into a physical representation (neural signaling) inside their heads and then back into physical action on the environment (movements, speech, and other observable behavior).

Take vision, for example. The human perceptual system comprises a set of processing steps that somehow transform a two-dimensional pattern of photons on the retina into a neural experience of colored, textured objects existing around us in three-dimensional space. It has taken us some time to realize exactly how difficult and computationally challenging the investigation of these basic functions is. In an oft-told (possibly apocryphal) tale, Marvin Minsky, one of the founders of the field of artificial intelligence, assigned the problem of computer vision to a student as a summer project. Thirty years later,

we are still struggling to identify the translational algorithms that guide basic perceptual and motor systems, as well as those behaviors that appear uniquely part of the human mental repertoire, such as language, reasoning, and forms of social thought.

Until about twenty years ago, most of our knowledge about the way the brain produces the mind relied on studies of patients with specific brain damage from a stroke or head injury, or on tentative extrapolation from experiments on non-human animals. However, recently developed techniques for functional imaging and virtual lesioning have finally allowed researchers to examine the living, healthy human brain as it goes about its business of processing information. Methods such as functional magnetic resonance imaging (fMRI), its predecessor, positron emission tomography (PET), and newer techniques such as near-infrared spectroscopy (NIRS) now allow researchers to pinpoint areas in which metabolic activity—for example, greater blood flow—increases when participants perform a particular task. In addition, more exotic techniques—such as transcranial magnetic stimulation (TMS), in which rapidly changing magnetic fields are used to create short-lived electrical disruptions of cortical function (virtual brain lesions)—enable researchers to catalog the behaviors that humans can and cannot perform when the functions served by a particular brain region are temporarily disabled. These techniques have dramatically accelerated our scientific understanding of the human mind, permitting a direct look at the underlying hardware on which our mental algorithms are being run.

Two assumptions about the brain allow these new brain-imaging methods to inform the study of human cognition.

First, we generally presume that different brain regions have different processing portfolios—that is, that different brain regions are likely to serve distinct subroutines of the mind. Second, brain regions are thought to serve a limited number of processing operations, perhaps only a single specific type of computation. These two working assumptions allow powerful insights into the organization of the mind.

Imagine that a researcher is interested in the question of whether perceiving and identifying the faces of other people (“That’s John Travolta!”) relies on the same types of information processing as perceiving and identifying inanimate objects (“Is that a white leisure suit he’s wearing?”). As it turns out, these two mental abilities engage neighboring, but distinct, brain regions, suggesting that different cognitive processing—different transformations of incoming information—takes place between the point at which photons impinge on one’s retina and the point at which one has the conscious experience of perceiving either a face or an inanimate object. If, on the other hand, face and object perception relied on the operation of the same brain regions, researchers would have probable cause to infer that the same kind of information processing mediated between the retina and an understanding of what one was looking at. If either of these two assumptions turns out to be untrue—for example, if different brain regions often serve the exact same mental operations—the use of brain imaging to inform psychology will prove severely limited. Fortunately, thus far, psychologists have no reason to doubt that the brain is organized like other machines, composed of parts that perform specialized and distinct functions.

In this way, neuroimaging has unearthed some unexpected

features of human psychology—features once underappreciated. For example, it seems that our recall of past events, rather than being a single, monolithic operation, can be deconstructed into several distinct processing mechanisms. The brain regions that contribute to memory vary depending on what kind of information is to be remembered (faces, words, locations), whether one needs to recall specific details of an event or merely the gist of it, and how long ago the memory was encoded. Conversely, neuroimaging studies suggest that some mental experiences we think of as being distinct from one another actually rely on the same information-processing circuits: for example, imagining an object (your cat’s ears, say—are they pointy or floppy?) engages some of the same visual-processing areas that serve real-world perception—that is, actually seeing a cat in front of you. By demonstrating that some mental experiences feel unitary but comprise multiple processes, whereas others feel distinct but rely on the same processing areas, neuroimaging has forced psychologists to reconsider many of the intuitive divisions and theoretical constructs that developed before we could so easily examine the neural hardware on which the mind runs.

Perhaps the least anticipated contribution of brain imaging to psychological science has been a sudden appreciation for the centrality of social thought to the human mental repertoire. Although *Homo sapiens* surely owes much of its evolutionary success to our unparalleled ability to reason in flexible and novel ways, the most dramatic innovation introduced with the rollout of our species is not the prowess of *individual* minds but the ability to harness that power across many individuals. Indeed, the scale and complexity of human behavior—including our current

world dominance—is supported in large part by mechanisms that allow us to coordinate large groups of people to achieve goals that individuals could not. Consider the number of people required to design, construct, and operate an airplane, erect a building, or run a national government.

In order to integrate the behavior of many individuals, the human mind must be capable of at least two kinds of special processing. First, to have any hope of coordinating the minds of others, we must have a way to understand what's happening inside them—that is, a set of processes for inferring what those around us are thinking and feeling; what their goals, desires, and preferences might be; and what personality traits and temperament differentiate them from other people. In other words, we have to be “mind readers,” capable of perceiving the mental states of the people around us. Second, we must possess tools not only for passively inferring the contents of others' minds but also for actively influencing what others think and feel. The surest way to enable one to know what's on another person's mind is to implant one's own thoughts and feelings into the other's mind, and humans have unique and remarkably powerful means of doing this. Human language can be considered primarily a vehicle for transferring one's own mental states into another mind. Humans are the only animals that explicitly attempt to affect the content of others' minds through direct instruction. Although other primates may try to manipulate the mental states of their conspecifics (for example, through deception), they do not appear to attempt to reproduce their own mental states in other minds.

The emerging field of social neuroscience has suggested that these interpersonal abilities draw on several unexpected

characteristics of the human brain. Natural selection has designed specialized regions whose activity appears to be specifically dedicated to the task of understanding the goings-on of other people's minds. Dozens of neuroimaging studies have examined the pattern of neural activity that differentiates between tasks that require the consideration of another person's mental state (How happy does this person look in the photograph?) and those that require consideration of the non-mental qualities of a stimulus (How symmetrical is this person's face?). These studies have uncovered a set of brain regions that are preferentially engaged during “mind reading”: the dorsomedial prefrontal cortex (a region immediately behind your forehead and in line with your nose), the temporo-parietal junction (so named because it is found where the parietal and temporal cortices meet, about two inches above and two inches behind your ears), and the medial parietal cortex (immediately below the crown of your head). In fact, the observation of activity in these regions during social tasks may be the most consistent finding in all of cognitive neuroscience.

Even more intriguing, these brain regions are marked by an unusual property. When people are left to lie quietly in an MRI or PET scanner without any particular task to perform, most of their brain decreases in activity. However, the brain regions identified during mind-reading tasks continue to churn away. This chronic engagement of “social brain” regions suggests that the human brain has a predilection for contemplating the minds of others. Our tendency to anthropomorphize—to see mind where none truly exists, as in inanimate objects or the forces of nature—may well result from the chronic overactivity of those brain regions implicated in social thought. Human

minds seem always at the ready to tackle another mind, a proclivity that may lead us to perceive the world as being chock-full of other mental agents.

The special neural status of social thought is further suggested by another unusual feature of these brain regions: they tend to deactivate when a person thinks about something other than a mind. Brain regions that serve other mental functions do not generally exhibit such decreased activity when their particular information-processing services are not required. For example, brain regions involved in arithmetical calculations do not "shut off" when you think about something other than numbers; they simply cease responding over and above their resting rate of metabolism. Not so for brain regions involved in social thought, which routinely show decreased activity when not in use. This peculiar—and poorly understood—aspect of social-brain regions suggests that social thought may be an activity incompatible with other kinds of information processing. Perhaps our mental algorithms cannot simultaneously remain vigilant for the presence of other minds and also interact with entities that are inherently mindless (such as mathematical operations or inanimate objects), but must instead suspend the tendency to approach the world in a social manner when faced with nonminds. If we were unable to suppress the predisposition to see all things as having a mind, think how hard-hearted we'd have to be just to pour scalding water into a mug, pound a nail, or slam-dunk a basketball.

Finally, social neuroscience has begun to demonstrate just how exquisitely sensitive our minds are to the goings-on of the minds around us by suggesting that our brains spontaneously mirror the pattern of activity of other brains in our vicinity.

When we see a person who looks afraid, our brain responds in the same way it does when we experience fear ourselves—by activating a small region in the brain known as the amygdala. When we see someone about to slam a door on his finger or being injected with a syringe, our brain responds as though we ourselves were experiencing pain—by activating the anterior cingulate cortex. People also often wince in virtual pain when they see or contemplate others undergoing such experiences. If we were to see another person take a deep whiff of rotting garbage, our brains would respond as though we ourselves were disgusted, by activating the insula. And if we watch another person try to achieve a particular goal (such as picking up a desired object), our brains respond as though we were doing the same, by activating so-called mirror areas in the parietal and frontal lobes. Such observations suggest that the human mind naturally attempts to engage in the same kinds of information processing as neighboring minds—that our brains prefer to be in register with the brains around us. Although the implications of this nascent discovery have yet to be explored in full, our drive to get on the same mental page as other people hints at a hidden complexity in human social interactions that includes our brains simultaneously struggling to figure out and to adopt the same processing states as those of others.

These observations about the brain's social proclivities have refocused a good deal of psychological research on the problem of just how the mind engages with other minds. Successfully interacting with, predicting, or influencing the mind of another person requires an extraordinary set of cognitive skills. What kinds of information-translation processes transform a partner's raised eyebrow or sideways glance into an

understanding of that person's thoughts and feelings? What processes transform one's mental states into complex utterances, complete with a pragmatic awareness of what a listener can comprehend (as shown by, for example, differences in the way we speak to children and adults)? We've only just begun to figure out the answers to these questions, but armed with new technologies for imaging the living human brain and a new appreciation for the importance of social thought, psychological scientists may soon be able to unravel the mind's intricate dance as it responds to, influences, and is influenced by other minds.