Think Different

The ways in which brains differ from one another shows up in the way their owners perceive the world

BY CHRISTOF KOCH

PERCEPTUAL PSYCHOLOGY and the brain sciences emphasize the communality in the way that people experience reality. Leaving aside cases of brain damage or mental disease, we all see the sun rise in the east, enjoy the scent of a rose and experience a jolt of fear when we are woken up in the middle of the night by the sound of breaking glass. This is a reflection of the great similarities of our brains compared with the brains of our close cousins on the evolutionary tree, the great apes. Laboratory science reinforces this bias by lumping together the performance of its subjects on any one experiment and reporting only the average and the variation around this mean. This conflation is also true for the telltale hot spots that show up in functional magnetic resonance brain images that we are used to seeing in newspapers, in magazines such as this one, on television and in the movies.

Yet as we know from our own life, each one of us has his or her own preferences, likes and dislikes. Some people are acutely sensitive to flashing lights, some have perfect pitch, some cannot see in depth, some can introspect and analyze their own failures and triumphs, whereas others—remarkably frequently, public figures such as politicians—lack this knack. Take me. I am hopelessly attracted to brilliant colors. As a magpie is drawn to anything glittering, I am drawn to school-bus yellow, tangerine orange, burgundy red, rich magenta, electric violet, imperial purple and navy blue. My love of the garish is reflected in my flowery shirts and pants and, I'm sure, in an enhanced cortical representation of these hues.

It is obvious that if the apparatus that senses the world differs between two individuals, then the conscious experience of the brains wired to these sensors cannot be the same either. In a previous

CHRISTOF KOCH (*Koch*); CORBIS (*rose*)

Consciousness Redux column, I discussed color blindness—the fact that about 7 percent of men lack one of the genes for the retinal photopigments needed to see hue. But what about differences in the brain proper? Do they influence consciousness in measurable ways? To answer this question, scientists must plumb the minds of many individuals and relate them to measures of their brains. The widespread availability of fMRI scanners makes such a project feasible today.

Cognitive neuroscientist Geraint Rees, a professor at the Wellcome Trust Center for Neuroimaging at University College London—undoubtedly the world's leading fMRI center—published a trio of studies that relates differences in the way people experience things with differences in gross aspects of their cerebral neocortex, the highly convoluted part of the forebrain that crowns the brains of all mammals.

In one study 30 subjects looked at the Ponzo [*see illustration on opposite page*] illusion while their brains were scanned. Whereas everybody who looks at the Ponzo perceives the upper bar as larger than the lower one, the magnitude of this effect differs substantially across individuals. (The size of the illusion is established by asking how much larger the lower bar has to be to make it look the same size as the upper one.) Surprisingly, these differences are reflected in the surface area of the primary visual cortex (V1) at the back of the head. For unknown reasons, the area of V1 can differ by a factor of three among people (unfolded, the size and width of a typical V1 compares with that of a credit card). Rees and his collaborators discovered that the smaller a person's V1, the more powerfully he or she experiences the illusion. Those individuals with a large V1 judged the size of the bars to be more similar than those with a smaller V1. Curiously, the size of the two immediately adjacent visual areas did not influence the amplitude of the illusion.

Clues from Illusions

Bistable illusions are those delightful images that can be seen in one of two ways. Probably the best known is the

Can differences in this higher-order **aspect of consciousness** be tied to differences in brain structures? Yes.

Necker cube, or the "old woman, young girl illusion." These two interpretations flip back and forth. The time it takes for the percept to flip differs consistently across individuals. One person might see the figure alternate every five seconds; another sees it flip every 10.

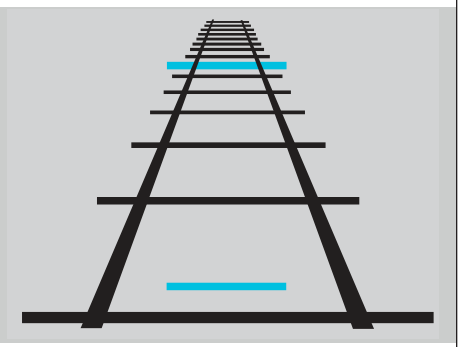
Rees and his group used a dynamic version of such bistable illusions: a cloud of moving dots perceived as a cylinder rotating either to the left or to the right. Here the scientists correlated the width of the cortical sheet—the thickness of its gray matter—with how long each stable percept lasts before it switches. Scanning the brains of 52 subjects—in a field dominated by studies that come to grand conclusions by querying a handful of brains—they found only a single region, the left and right superior parietal lobe (SPL), in which the thickness of the gray matter (and its density) significantly and consistently correlated negatively with the perceptual duration. In other words, the thicker the SPL cortex, the faster two interpretations switch back and forth. It is known from other imaging and clinical studies that the SPL in the back of the brain controls selective visual attention, but how the thickness and density of SPL gray matter should be important is anybody's guess.

Ask people what they believe to be the defining feature of consciousness, and most will point to self-awareness. To be capable of being aware of your hopes, to worry about your spouse's illness, to wonder why you feel despondent or why he provoked you is taken to be the pinnacle of sentience. Self-awareness is, by and large, absent in nonprimates. Although my dog—as with many and, perhaps, all animals—experiences the sights, sounds and, in particular, the smells of life, she doesn't worry why her tail isn't wagging as it used to or whether tomorrow's food will appear.

So can differences in this elusive higher-order aspect of consciousness be tied to differences in brain structures? Yes, as a just published third study by Rees and his colleagues concludes.

Thirty-two healthy volunteers carried out a difficult visual task in the scanner. They had to judge which one of a number of faint patches was a tad more salient than the other ones; this judgment was purposefully made demanding. Following each trial, subjects had to choose a number between one and six, indicating the confidence they had in their own judgment. A six indicated that they were very confident of their judgment, whereas a one implied a guess. That is, they were asked to introspect: Are you sure you just saw the bright patch here? Psychologists know this as meta-cognition: thinking about thinking.

Not surprisingly, subjects differed greatly in the accuracy of their judgments (independent of the level of their performance). Think of the game show *Who Wants to Be a Millionaire,* where contestants have to judge whether they want to use a lifeline before they know the answer, depending on their confidence. Some people are astute, using the lifelines wisely; other people fritter them away. The cognitive scientists extracted a measure of variability of introspection and discovered that this measure correlated with variability in gray matter volume in the right anterior prefrontal cortex. The more neurons you have in this region in the front of the brain, the better your introspection. Not that your performance goes up, but the insight you have into your performance—whether you thought you did well or not—increased. Patients with lesions in these regions typically lose the ability to introspect. And this part of the neocortex has expanded more than any other region in primates. Again, the neuronal mechanisms underlying this correlation remain unknown for now.



The Ponzo illusion provides a visual cue of converging railroad ties, so the upper blue bar is perceived to be farther away—and thus much larger—than the lower blue bar. Yet they are exactly the same dimensions. The smaller the size of your primary visual cortex, the more dramatic the illusion.

Rees's studies establish that differences in the morphology, or shape, of our brains are mirrored in differences in the way we consciously experience and apprehend the world, including our own brains and bodies. In this way, neuroscience maps the physical structure of the material brain onto the inner geometry of phenomenal and ineffable experience. **M**

CHRISTOF KOCH is Lois and Victor Troendle Professor of Cognitive and Behavioral Biology at the California Institute of Technology. He serves on *Scientific American Mind*'s board of advisers.

(Further Reading)

- **Human Parietal Cortex Structure Predicts Individual Differences in Perceptual Rivalry.** Ryota Kanai, Bahador Bahrami and Geraint Rees in *Current Biology,* Vol. 20, No. 18, pages 1626–1630; August 19, 2010.
- **Relating Introspective Accuracy to Individual Differences in Brain Structure.** Stephen Fleming, Rimona Weil, Zoltan Nagy, Raymond Dolan and Geraint Rees in *Science,* Vol. 329, pages 1541–1543; September 17, 2010.
- **The Surface Area of Human V1 Predicts the Subjective Experience of Object Size.** Samuel Schwarzkopf, Chen Song and Geraint Rees in *Nature Neuroscience* (in press).