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Seeing Through a Ceiling Fan

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The retrograde rotation of wagon wheels in Western movies is a digital illusion of continuous motion. But vision itself is not continuous and it's not clear that the "stream" of consciousness that perceives it is continuous either.

It is often said that consciousness is the last great frontier of biology, and indeed it is not well understood. The challenge to find scientific methods that can explain a subjective phenomenon is certainly great and unique. We have to come at this challenge from within the *gestalt* of our own experience, because we have no direct way to know what anybody else's experience is like or whether other animals even *have* consciousness—whatever it is.

A number of recent reviews and books have appeared on the subject, suggesting that the situation is changing thanks to advances in neurobiology and innovations in imaging and other experimental techniques. Claims of major advances may be exaggerated, because a comparison of the earliest works of modern psychology bear striking similarity to the most recent. But much has been learned, raising thought-provoking issues, including questions about the evolution of consciousness. Consciousness feels like continuously streaming experience rather than discrete interrupted sequences. But studies of visual perception show that the neural reality is more subtle, and thus more interesting.

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VOYAGES TO INNER SPACE

A persistent problem in attempts to understand consciousness is that there is no agreement about what the phenomenon really is. The problem is captured by the concept of *qualia,* which refers to things like the "redness" of red or the aesthetics of tonal harmony.

For millennia in western thought, consciousness was associated with a concept of the soul. Attempts to bring this under the tent of modern science largely began under the influence of Darwin, with influential work by founding thinkers like the psychologist William James (1842–1910),[1] and the philosopher Henri Bergson (1859–1941).[2] Science was more phenomenological then than it is today, and in the absence of any way out of the subjectivity problem there was a vitalistic core in the work of both authors. James threw his hands up and suggested we should just "say *the Soul* and have done with it" and put our attention on the "succession of total brain-processes" that can actually be observed. Bergson was unapologetically mystical (Fig. 1). His famous *Creative Evolution,*[2] tried to explain consciousness—and indeed the basic nature of evolution—as essentially due to an inner immaterial force, the *élan vital,* that brings forth new traits by acting on inert matter, perhaps like Michelangelo's slaves struggling to get out of blocks of marble.

During the 20th century, psychology became an ever more experimental neuroscience. The modern view was reflected about a decade ago in *The Astonishing Hypothesis: The Scientific Search for the Soul,*[3] by Francis Crick, who with James Watson had previously worked out the structure of DNA. Crick asserted that consciousness is a strictly neurocellular affair. He had taken astonishing positions in his day, like suggesting that life was sent here from outer space. But there's nothing astonishing about a claim that inner space is strictly a neural phenomenon, at least not for scientists.

Along with others, Crick and longtime collaborator Christof Koch (Figure 2) have recently summarized current consciousness research.[4–8] Like James, but without his resigned acceptance, investigators take an indirect approach, and search for "the minimal set of neuronal events that gives rise to a specific aspect of a conscious percept,"[4–7] the *neural correlates of consciousness* (NCC). This is a new phrase but basically a re-minting of James' view in 1890. At least today we have the advantage of much more data, ranging from animal experiments in which a few or even single neurons are monitored, to external imaging of localized brain activity such as by functional Magnetic Resonance Imaging (fMRI) during reported experience or task-performance. Sadly, the ever-creative Crick has just died at age 88, ceasing to produce any NCC of his own, and passing beyond any expectation he had of finding answers.

An important fact of our experience of consciousness is that we *feel* as if there is a continuously monitoring "workspace" or "homunculus" in our heads that watches over our mental activity (an idea James referred to as a

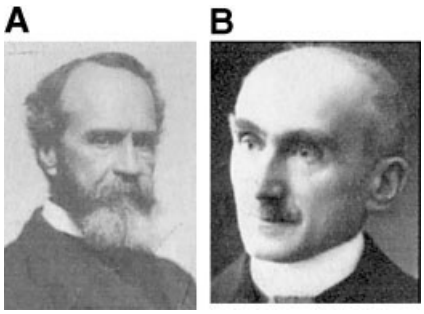

Figure 1. A: William James. B: Henri Bergson gazing inwardly at his *élan.*

pontifical cell). Sets or "coalitions" of neurons receive and process many different kinds of input including sensory and physical information, memory, and so on. We know that these raw bits require "binding," or synthesis into what we eventually perceive as unitary experiences. The neural coalitions compete for the attention of the monitor, and the successful winner gains our conscious awareness.[4,7,9] (Ah! *Now* I remember her name!) Imaging studies show that these activities involve separate parts of the brain, but it remains controversial whether consciousness itself is localized, for example, in the frontal cortex, or is broadly disseminated.[6]

THAT OLD "VISION" THING

Since there doesn't seem to be a pontifical cell we could wire up directly, investigators like Crick and Koch have settled attention on a particularly accessible source of NCC, *vision.* Vision is not necessary for consciousness—blind people, including sighted people who *become* blind—are fully conscious. But vision at least contributes to conscious awareness, and brain activity can be monitored while images are manipulated or subjects report their visual perceptions; and we can do direct experiments. The psychological responsiveness of macaques has made them the traditional animal model of choice for such work.

A lot is known about the mechanics of vision. Signal from incoming light is modified by interconnections among retinal cells before it leaves the eyes, and then further processed by and distributed to many parts of the brain. A major fraction of the activity of the cerebral cortex is devoted to vision. The six neural layers of the visual cortex at the back of the brain play different, though overlapping roles, separately handling intensity, hue, edges of intensity change, angles, certain shapes like faces, and motion.[4,5]

The binding of these attributes occurs before the result is perceived consciously, as we might guess from the routine experience of driving a car without really paying much attention. In fact, natural human or experimental-animal focal brain injuries show that an individual can detect and respond to visual images entirely without being aware of them in the usual conscious sense.[5] Authors from James to the present have frequently illustrated automated processing with optical illusions, like Figure 3, that can be so strong as to require deliberate conscious concentration to rectify. But what happens is not entirely simple. In those rare persons who first gain sight later in life because of medical intervention, motion detection seems to work automatically, but other aspects of vision including object-recognition seem chaotic, apparently needing to be established through early and probably conscious experience, perhaps the way we learn language (many subjects wish they had remained blind).

The visual perception of *motion* has long been seen as a window on the nature of consciousness, but this raises many interesting questions. In James' time, zoetropes (Figure 4A) were a popular amusement. Zoetropes present a quick succession of slightly altered still images that produces an illusion of continuous motion. The idea evolved into cinematography during Bergson's life. Both authors thought the brain worked in a similar way, by taking selective "snapshots" of its underlying inner neural world, and filling in the gaps somehow to make existence seem continuous.[10]

However, the cinematic analogy is imperfect. Everyone is familiar with the curious experience that wagon wheels in Western movies seem to rotate backwards while the horses pull the wagon forwards. This retrograde motion is of course an artifact of cinematography. The rotation itself may be continuous, but each photographic instant is so fast, like that of my ceiling fan in Figure 4B, that it appears to freeze a fixed state, with motion reflected only by a blurry background. Running these images out of synch makes the fixed positions appear as if they are moving backward. But out of synch relative to what?

A still camera exposes all its pixels in the same discrete moment of time (although the moving shutter leaves outer and inner areas exposed at slightly different intervals). The 200 million retinal cells in our eyes work differently. They receive streams of photons continually, and unlike a camera, retinal cells re-

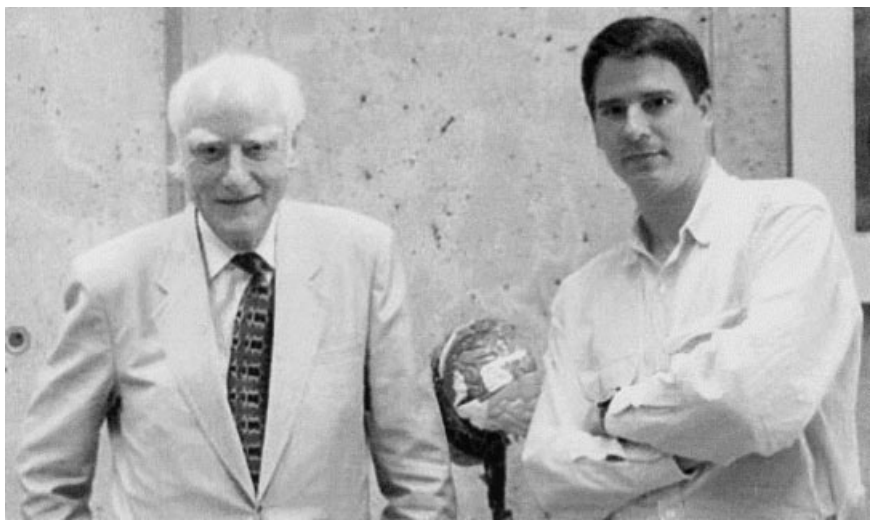

Figure 2. The late Francis Crick (left), Christof Koch (right), brain (center: consciousness state unspecified). Reprinted with permission from Koch's web page.

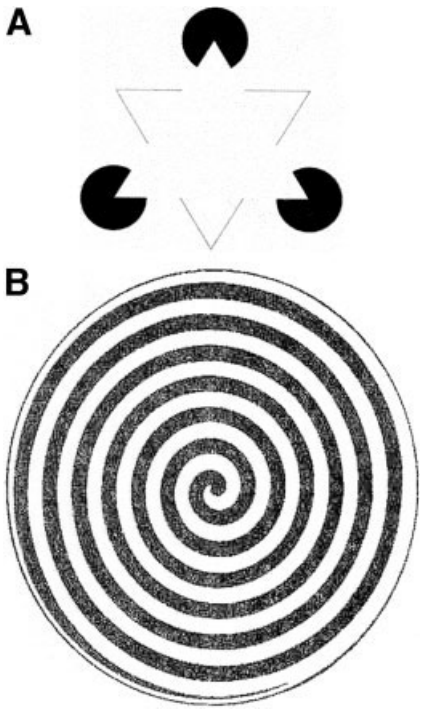

Figure 3. Optical illusions. A. Kanizsa figure (there are no triangles in the figure). B. Does it move? (From [1].)

fresh independently, as the chromophore molecules in their photoreceptors are individually restored after being modified by light energy. Televisions and computers present images captured in another way, by refreshing pixels sequentially, in lines going left to right and down the screen 60 or more times a second.

A movie strikes the retina as an artificially synchronized sequence of whole images, each from a separate moment in time, but a moving object hits the retina as a dynamic process different for each retinal cell. These various artifactual ways of turning freeze-frame into continuity somehow have similarities to our own internal processing. Figure 4B is from a camera, but that's also how my ceiling fan looks directly to *me*. What generates the blur, and how, though I'm not Superman, can my eyes see through the blade to the post above it?

The brain turns these very different styles of input into the same experience of continuous motion.[11] It is still mysterious how this works. For example, even when it can clearly see that wagon in the movie is itself moving forward, our homunculus accepts backwardly filled-in gaps in the wheels. S/he can also impishly make things move that are perfectly still, like Figure 3b. The brain can also stretch and distort the continuity of consciousness as when it slows our perception of time during impending emergencies like car crashes.[14]

One thing we know that may be relevant is that the brain is very good at noticing what *changes*. A focus on change may be an efficient way to generate a sense of continuity of consciousness the way cheap cartoons on Saturday morning television simulate motion, even though only small bits of each successive cel are modified (this must be fundamentally neural, judging by how it stupefies the brains of children).

The "synch" in vision seems to have to do with the timing of gaps in incoming images relative to some kind of cycling phenomenon in the brain. Like the retina, the brain is a pulsing organ. Individual neurons fire in discrete events and must be refreshed in between, as their action potential is restored or neurotransmitter molecules cleared form cell-surface receptors. Each pulse is discrete, but a neuron may synapse with 10,000 other neurons, which may be induced to fire in response. The resulting signal cascades are going on all the time as diverse information (light, odor, sound, body position, temperature, nutritional state, etc.) and is analyzed in different parts of the brain, all flashing around in fMRIs like the Northern Lights.

In James' time some viewed consciousness as "the 'integration' of a thousand psychic units." In today's terms, competing "coalitions" of discretely pulsing neurons may not be centrally synchronized, but 200 million retinal cells and 100 billion neurons in our brains may be so practically infinite as to be effectively continuous in perception. Many investigators have suggested that consciousness is an epiphenomenon of scale, an extra-cellular aura of the electromagnetic field produced by a vast number of firing neurons. Neuron firing does induce local electromagnetic fields in the brain, but there is a problem with this view: billions of neurons fire when you're asleep or unconscious, and people who have surgically lost half their brain are still conscious, yet the right half which is the same size as the left doesn't have the same kind of awareness. And there is no evidence that people with larger brains have more consciousness.

Depending on what consciousness actually is, it is not clear how size matters, because as Darwin observed "the wonderfully diversified instincts, mental powers, and affections of ants are notorious, yet their cerebral ganglia are not so large as the quarter of a small pin's head. Under this view, the brain of an ant is one of the most marvelous atoms of matter in the world, perhaps more so than the brain of a man."[12] (Figure 5).

EVOLUTIONARY CONSIDERATIONS AND AN IRONIC TWIST

The process of evolution is a somewhat analogous mix of discreteness and continuity. This is relevant because if evolution had produced every other trait in this way, one would have to be a vintage saltationist to argue that this one trait alone, consciousness, suddenly arose ready-made in some stunned hominid. Continuity is at the heart of must Darwinian theory. One implication is that the essence of one person's experience of consciousness is similar to another's and, by

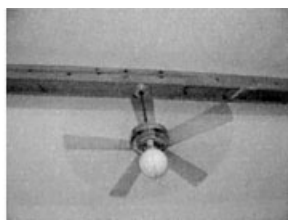

Figure 4. Illusions of motion. A: 19th century zoetrope's illusion. B: Quick as the wink of a camera's eye. My ceiling fan, and *my* internal illusion, too.

Figure 5. Fire Ants. (What) are they thinking?

extension at least, somewhat similar to that of closely related species—whether or not we can extend that all the way to ants.

Still, a number of scientists confer the blessing of consciousness on ourselves alone, sometimes arguing that only humans even have the ability to *think.*[13] This is hubris at the very least, like post-war history that can only be written by the winners since the losers are dead. It's an exceptionalism that seemed anti-evolutionary to me even before I learned that Rico the German dog could understand over 200 words. Of course, the possession of consciousness by other species past or present doesn't mean the trait was *identical,* but we have to entertain the intriguing likelihood that more primitive versions of consciousness might be only a partial, foggy or intermittent awareness (experience that drugs and sleep can simulate even in us). Evolutionary continuity at least puts a burden of proof on those who claim it is erroneous anthropomorphizing to attribute sadness or happiness to a dog or goat.

We can only go so far in studying consciousness in humans, but what we can learn from other species will be disputable so long as what consciousness is depends, to paraphrase our recent President on a somewhat different subject, on what the meaning of "is" is. Consider the mental life of monkeys, from which so much of what we consider to be relevant knowledge has come.

In fact, we do have knowledge on this question. A number of people with uncontrollable epilepsy have had the fibers of their *corpus callosum* severed. That keeps seizures from spreading by separating the neurons that connect the two hemispheres of the brain. After the surgery these "split-brain" patients report no loss of their unitary sense of self or consciousness.[9] Patients hemisectomized for other reasons report the same. However, the two hemispheres in split-brain subjects have been shown to be unaware of each other, and only one (usually the left) can report conscious phenomena via language, as if it alone contained the person's homunculus as the sole home of consciousness. Yet experiments show that the right side is still working away solving fully complex human problems, with whatever kind of awareness that requires.

Split-brain findings force investigators of consciousness to take sides, so to speak. Like recent politicians, what they've done is to abandon the left and move to the right: they dismiss the relevance of language through a clever act of semantic severing, by *redefining* consciousness to be the kinds of things the non-verbal right hemisphere is doing. If consciousness is newly defined as "problem solving," we no longer have to find what's specifically different about the classically conscious left side, which would be challenging since the two hemispheres are neurally about the same (wiring, neural centers, numbers of connections or firings, etc.). Redefining consciousness also conveniently solves important evolutionary as well as practical objectives by a subtle opposite to severing. It rejoins humans with other species, so we can move our study of human consciousness into the experimental animal lab—without having to prove that monkeys even *have* what really needs explaining. Now *that* is an act of perceptive grantsmanship!

WITHIN EACH PERSONAL CONSCIOUSNESS THOUGHT IS SENSIBLY CONTINUOUS[1]

James' and Bergson's views were picked up by the stream-of-consciousness movement in literature and influenced impressionism and pointillism as well. Bergson himself won the 1927 Nobel prize in literature for "the intuitive discovery that opens the gate to the world of his thought."

But mental experience did not have to be continuous. Insects do very well in the fundamentally digitized visual world of their compound eyes with hundreds of independent ommatidia. Even our own vision is largely based on discrete frame-freezing. There is no reason why consciousness couldn't have evolved to be perceptually discrete as well. But that is not what happened. Instead, the brain turns complex, digital, neural chaos into the holistic continuous phenomenon: *Me!*

Molecular empiricism has expunged any tolerance for vitalism, but the conceptual issues—most of the issues I have discussed here—have not changed very much. We still have not solved the qualia problem. The NC's being identified aren't even unambiguously NCC's, as long as our definitions, and not the facts, determine what we're monkeying around with.

NOTES

I welcome comments on this column: kenweiss@psu.edu. I have a feedback page at http://www.anthro.psu.edu/weiss lab/index.html. I thank Anne Buchanan, Jeffrey Kurland, Sam Sholtis, and John Fleagle for their very helpful comments.

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