SCIENCE

The Human Brain Evolved When Carbon Dioxide Was Lower

There is substantial but inconsistent evidence that as carbon-dioxide levels rise, they could affect human cognition.

ROBINSON MEYER DECEMBER 20, 2019

AustraliaÕs bushfires choked Sydney with soot and have emitted about 195 million tons of carbon dioxide this year, equivalent to half of the country's normal carbon-emissions footprint. (REUTERS)

SAN FRANCISCO—Kris Karnauskas, a professor of ocean sciences at the University of Colorado, has started walking around campus with a pocket-size carbon-dioxide detector. He's not doing it to measure the amount of carbon pollution in the atmosphere. He's interested in the amount of CO_2 in each room.

"I did this at home, just having fun with it, and in a bedroom overnight it can get over 1,000 parts per million very quickly," he told me. Even *here*, he added—gesturing at the city-block-size basement of the Moscone Convention Center, filled with thousands of earth scientists milling about their discipline's giant annual science fair—the CO_2 probably exceeds 500 parts per million.

The indoor concentration of carbon dioxide concerns him—and not only for the usual reason. Karnauskas is worried that indoor CO_2 levels are getting so high that they are starting to impair human cognition. In other words: Carbon dioxide, the same odorless and invisible gas that causes global warming, may be making us dumber.

"This is a hidden impact of climate change … that could actually impact our ability to solve the problem itself," he said.

He proposed the idea last week at the American Geophysical Union's fall meeting, the largest annual gathering of earth and space scientists in the world. He also previewed it in an online paper written with Shelly Miller, a mechanical-engineering professor at the University of Colorado, and Anna Schapiro, a neuroscience professor at the University of Pennsylvania. The paper, while not yet peer-

reviewed, was uploaded to a website where academics can discuss early-stage or provocative research.

[Read: A popular benefit of houseplants is a myth]

The science is, at first glance, surprisingly fundamental. Researchers have long believed that carbon dioxide harms the brain at very high concentrations. Anyone who's seen the film *Apollo 13* (or knows the real-life story behind it) may remember a moment when the mission's three astronauts watch a gauge monitoring their cabin start to report dangerous levels of a gas. That gauge was measuring carbon dioxide. As one of the film's NASA engineers remarks, if CO_2 levels rise too high, "you get impaired judgement, blackouts, the beginning of brain asphyxia."

"They knew they're going to go nuts and not do 2+2 if that gauge gets too high," Karnauskas said. The same general principle, he argues, could soon affect people here on Earth. Two centuries of rampant fossil-fuel use have already spiked the amount of CO_2 in the atmosphere from about 280 parts per million before the Industrial Revolution to about 410 parts per million today. For Earth as a whole, that pollution traps heat in the atmosphere and causes climate change. But more locally, it also sets a baseline for indoor levels of carbon dioxide: You cannot ventilate a room's carbon-dioxide levels below the global average.

In fact, many rooms have a much *higher* CO_2 level than the atmosphere, since ventilation systems don't work perfectly. On top of that, some rooms—in places such as offices, hospitals, and schools—are filled with many breathing people, that is, many people who are themselves exhaling carbon dioxide. As Karnauskas said: "We're little CO_2-producing machines ourselves."

"Imagine a conference room," he said. "You have middle-aged people—20 of them—sitting in a small room, breathing. That CO_2 easily exceeds 1,000 parts per million."

And that leads to the final part of his and his colleagues' argument: As the amount of atmospheric CO_2 keeps rising, indoor CO_2 will climb as well. They project that, in a worst-case emissions scenario, it may be impossible to ventilate a crowded room below about 1,300 parts per million. That could induce some real cognitive damage. In 2016, researchers at Harvard and Syracuse University found that human cognitive function declined by about 15 percent when indoor CO_2 reached 945 parts per million, and crashed by 50 percent when indoor CO_2 reached 1,400 parts per million.

Under a very high carbon-emissions scenario, "our complex decision-making functions could be reduced by as much as half by the end of the century," Karnauskas said.

[Read: The air pollutants in your medicine cabinet]

He and his colleagues admit that their calculations are back of the envelope. "There's got to be a lot more work on this," he told me. And I had to wonder: Is this for real? Why hadn't I heard about it before? Is carbon pollution not only heating the planet but actually making us more sluggish thinkers?

"I'd say it's possible but not necessarily plausible," Elliott Gall told me. He is a professor of engineering at Portland State University who studies indoor air quality. In 2015, after some of the early research on carbon dioxide and cognition came out, he wrote a paper speculating that companies could increase their productivity if they installed carbon scrubbers in office ventilation systems.

"Since then, we've learned a little bit more, but we know less," he said. There's been a surge of studies on the topic in the past few years. What they've found is inconsistent.

For instance, in one 2016 study Danish scientists cranked up indoor carbon-dioxide levels to 3,000 parts per million—more than seven times outdoor levels today—and found that their 25 subjects suffered no cognitive impairment or health issues. Only when scientists infused that same air with other trace chemicals and organic compounds emitted by the human body did the subjects begin to struggle, reporting "headache, fatigue, sleepiness, and difficulty in thinking clearly." The subjects also took longer to solve basic math problems. The same lab, in another study, found that indoor concentrations of pure CO_2 could get to 5,000 parts per million and still cause little difficulty, at least for college students.

But other research is not as optimistic. When scientists at NASA's Johnson Space Center tested the

effects of CO_2 on about two dozen "astronaut-like subjects," they found that their advanced decision-making skills declined with CO_2 at 1,200 parts per million. But cognitive skills did *not* seem to worsen as CO_2 climbed past that mark, and the intensity of the effect seemed to vary from person to person.

In September, some of the issue's leading scientists—including those from the Denmark lab mentioned above—reviewed all 10 studies on the topic since 2012. On moderate tests of cognition, they found, the evidence was very ambiguous: Sometimes higher CO_2 seemed to decrease ability, sometimes it didn't at all. But more worryingly, they noted "substantial, but still inconsistent, evidence" that human performance can decline on especially challenging problems at moderate concentrations. Pilot performance on flight simulators, for instance, starts to fall at 1,200 parts per million. "The mechanisms underlying the reductions in performance are unknown," they added.

In other words: There's evidence that carbon-dioxide levels may impair only the most complex and challenging human cognitive tasks. And we still don't know why.

[Read: U.S. carbon pollution surged after years of stasis]

In their September review, the authors noted that many aspects of the problem remain unexplored. For instance, does CO_2 make the effects of other brain-impairing pollutants worse? It's unclear. No one has looked at the effects of indoor CO_2 on children, the elderly, or people with health problems. Likewise, studies have so far exposed people to very high carbon levels for only a few hours, leaving open the question of what days-long exposure could do.

On top of all that, getting at the core question of human cognition is really challenging, said Gall, the Portland State professor. There isn't exactly a single, reliable, cross-cultural, widely applicable metric of human cognition. That's why some of the studies have used a "strategic management simulation," a method usually deployed in business and medical schools; studies on specialists such as pilots have used more specific tools, such as flight simulators. It's also nearly impossible to control the range of factors known to affect thinking, such as how much someone slept the night before. And most of the studies so far have been small, testing about 30 people at most. "It would be good to run at a size of hundreds or thousands of people," he said.

"The unfortunate conclusion," Gall said, "is, I think the science so far is unsettled for that direct role for CO_2" on human cognition. "Until we pinpoint CO_2 itself as a causative agent, there's a lot of ways that a changing atmosphere could impact indoor air quality."

Perhaps the most intriguing omission of the research is also the most ominous. Modern humans, as a species, are only about 300,000 years old, and the ambient CO_2 that we encountered for most of our evolutionary life—from the first breath of infants to the last rattle of a dying elder—was much lower than the ambient CO_2 today. I asked Gall: Has anyone looked to see if human cognition *improves* under lower carbon-dioxide levels? If you tested someone in a room that had only 250 parts per million of carbon dioxide—a level much closer to that of Earth's atmosphere three centuries or three millennia ago—would their performance on tests improve? In other words, is it possible that human cognitive ability has already declined? Gall said he wasn't aware of such an experiment.

But of course, a large-scale experiment is under way—it's just not happening under clinical conditions. You and I are its subjects, and the CO_2 in the chamber rises with every passing year. Clock your baseline cognition now: In another 20 years, you might miss these clearheaded times.

We want to hear what you think about this article. Submit a letter to the editor or write to letters@theatlantic.com.