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Cultural evolution: Is causal inference the secret of our success?

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A new study investigates hunters' causal understandings of bow design and mechanics among the Hadza, one of the last remaining foraging populations. The results suggest that sophisticated technology can evolve without complete causal understanding.

To refurbish the nuclear payloads that sit atop America's Trident II missiles, 21st century scientists needed to reproduce 'Fogbank' — a supersecret chemical catalyst last manufactured in 1989. While they retained the records and designs, most of the employees from that era were either retired or deceased, and the original manufacturing equipment had been dismantled. Consequently, even after seven years of intensive work, U.S. scientists still couldn't reproduce an acceptable batch of Fogbank. As this corner of the U.S.'s nuclear triad faced decommissioning, panicky government officials dumped $69 million into solving the mystery. Finally, after a Herculean effort, the scientists realized that the original method of purifying the input material was imperfect and left a chemical residue. This residue, it turned out, was actually a key catalyst in Fogbank. When the engineers first tried to recreate the old process, they had employed advanced purifying technologies and unwittingly eliminated this ingredient[1,2]. Those involved had initially assumed that the scientists understood how to make Fogbank — after all, they'd made it — but their causal model of the process had been critically incomplete. Nevertheless, despite their incomplete understanding, Trident missiles were weapons of terrifying destructive power.

The Fogbank case illustrates how human technology — and cultural evolution more generally — is not constrained by the limits of our causal understanding. In fact, across societies, people have long relied on a vast array of adaptive practices and tools that the makers themselves did not fully understand. To account for this, cultural evolutionists have argued that our complex technologies and sophisticated practices arise principally from our capacity to learn from others and transmit information across generations in a cumulative fashion. Models of these processes reveal how serendipity, recombination, transmission errors and learning biases operate across populations of minds and over centuries to generate increasingly sophisticated tools and technologies without the makers themselves possessing even vague intuitions about what's likely to work. In fact, this process can operate entirely outside people's conscious awareness and assemble technological designs or complex practices that contain numerous highly counter-intuitive elements. In this issue of *Current Biology*, Jacob Harris and colleagues[3] explore this by examining the causal intuitions of expert bow makers among a population of African hunter-gatherers.

Some argue that the cumulative cultural evolutionary process underpins much of

Figure 1. Causal inference and hunter-gatherer technology.
A Hadza father draws his bow, Tli'ika region, Hadzaland (photo: Jacob Harris).

our species' apparent creativity, and permitted paleolithic foragers to spread into an immense diversity of environments, from the dry savannah of the Rift Valley to the frozen tundra of the Arctic. Of course, compared to other species, humans are certainly intelligent, but our individual-level problem-solving skills are nowhere near powerful enough to assemble the stunning array of tools and practices that are responsible for our ecological dominance[4–6].

Interestingly, this view contradicts the common assumption that our technological prowess arises from our individual smarts. The psychologist Steven Pinker, for example, argues that our brains have genetically evolved an "improvisational intelligence" that allows us to build "cognitive stratagems on the fly"[7]. Pinker asserts that innovation occurs "when some person knuckles down, racks his brain, musters his ingenuity, and… invents something"[8]. Here, the process of technological improvement derives principally from individual brainpower, and specifically from our conscious efforts to devise, apply and culturally transmit causal models.

To reconcile these views, researchers have conducted laboratory experiments on cultural evolution, analyzed ethnographic cases, and scrutinized the role of causal models in the history of innovation[9–16] .Taken together, this work indicates that causal models are likely to have played a relatively small role compared to that of luck, recombination and the selective retention of more effective tools, techniques and manufacturing processes in driving technological change. However, it's not obvious that these insights, mostly derived from agricultural and industrialized societies, can be extended into our evolutionary past or readily apply to the technologies used by hunter-gatherers. Perhaps our minds have evolved genetically only to construct effective causal models for less complex technologies or for the kind of tools that were used recurrently over our evolutionary history.

To address this, Harris and colleagues[3] probed the intuitions of 64 Hadza men regarding various mechanical and design features of their key hunting tool — the bow. The Hadza, one of the world's few remaining populations of nomadic foragers, continue to subsist by hunting and gathering, including by pursuing wild game with bows and arrows across Tanzania's savannah woodlands (Figure 1). As hunting is men's primary economic activity, and the major source of their social status, boys begin enthusiastically learning to craft and use bows by middle childhood[17–19].

To fashion their bows, Hadza shape and smooth a limb — cut from a particular tree species — into a shallow arc using hot ashes, animal fat, beeswax and various carving techniques. Bows are then strung with spliced animal sinews, preferably from giraffes. This manufacturing process, which has been transmitted principally by observation and imitation, results in a powerful weapon that produces propulsive forces, efficiency levels and arrow velocities similar to those found in the 2012 Olympics, though Hadza pull ~70% of their body weight compared to only ~28% for the Olympians[20].

Bows have been a central tool in the human repertoire for at least 70,000 years, and Hadza bows are still used to bring down many of the same animal species that were hunted by our Paleolithic ancestors. If these Hadza men, who rely on their bows for survival and have been crafting them since childhood, lack key causal intuitions regarding bow design and mechanics, then it seems unlikely that the effectiveness of this ancient weapon derives primarily from our species' ability to make causal inferences.

Harris and colleagues[3] interviewed hunters in-depth about bows. In the process, they provided their causal intuitions in response to thirteen multiple choice questions. The queries included mechanical questions, such as "Will an increase in the draw weight (strength of pull) result in the arrow traveling faster, slower, or no change?" as well as design questions, such as "which bow profile will deliver the highest velocity arrows (the highest energy)"; participants were shown images of straight, deflex and recurve bows.

Out of the eight design questions, men's inferences were on-target only for three questions; strikingly, they did significantly worse than a random guesser on four of the questions, implying that their intuitions about bow design, and potential improvements, were systematically off target. For example, Harris and colleagues[3] asked, how would increasing the brace height — the distance from the bow's grip to the string at rest — affect an arrow's velocity? The answer is 'slower', but significantly fewer than one-third of Hadza interviewees correctly inferred this.

Similarly, Hadza were asked to make inferences about how a bow's curvature would influence an arrow's velocity. When asked how increasing the deflex in a bow would change an arrow's velocity, Hadza were correct nearly 90% of the time. This isn't surprising, as they could rely on their own direct experience with deflex. However, when asked to extend their causal modeling to a reflex bow, where the ends of the bow curve away from the shooter, nearly all Hadza got the wrong answer, not realizing that an arrow would depart at a higher velocity from such a bow. Notably, most Hadza have seen recurve bows in operation, but they are not part of their customary bow technology, so they lack hands-on experience.

On the mechanical questions, the Hadza performed much better, significantly beating chance on four out of five questions. Yet, as with the deflex question, these queries could be accurately answered based on men's direct experience. They knew, for example, that pulling harder — a greater 'draw weight' — would result in faster arrows. Tellingly, the one question that a majority of Hadza missed was whether one could reduce the twanging noise made by the bow string, which can alert the target. Just over half of all the hunters stated that there was no way to address this issue. However, over a third reported that a small cloth or sinew could be attached to the bow string to dampen the vibration. This is indeed an effective technique that is part of the traditional bow technology of some Native American groups. Indeed, some Hadza hunters have been observed to fasten cloth or sinew to their bowstrings, so those who suggested this answer may have been speaking from experience.

It seems that hunter-gatherers, like the Fogbank engineers, make and operate technologies that they themselves do not fully comprehend. Of course, both groups have partially correct causal models, but these are insufficient to account for the sophistication and effectiveness of their technology. In fact, we humans get much of our causal understanding by studying the functioning technologies that cultural evolution assembles for us. In this way, cultural evolution makes us smarter. Human innovation depends not on our individual brainpower but on our collective brains, on networks of diverse minds sharing information, lucky insights and chance recombinations in cumulative fashion. This is certainly true now, and — as the new study by Harris and colleagues[3] suggests — has been true for much of our evolutionary past.

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