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CHAPTER

The Cultural Niche

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Abstract

Humans are a different kind of animal. Our species has a bigger ecological range, cooperates on larger scales, and makes greater use of tools than any other vertebrate species. Many scholars argue that these novel features of human biology are the result of enhanced cognitive ability, especially the ability to create causal explanations of natural phenomena. An alternative hypothesis holds that cumulative cultural evolution has a central role, and that causal reasoning plays a secondary role. This chapter reviews this debate arguing that there are a range of models that differ about the role of causal reasoning, trial-and-error learning, and biased cultural learning. It then presents a laboratory study that indicates that cumulative cultural evolution can occur without causal understanding and an field study among Hadza hunter-gatherers that shows that the design of an essential foraging tool does not depend on a complete understanding of the costs and benefits of alternative designs.

Keywords: cognitive niche, cultural niche, cumulative cultural evolution, human evolution, evolution of technology

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Five million years ago our ancestors were like other late Miocene apes. They lived in a modest range of African habitats. Like living apes, they probably lived in small groups and made simple tools. By 10,000 years ago, human foragers were outliers in the natural world. Our species had a larger range, more biomass, more energy consumption, and cooperated in larger groups than any other terrestrial mammal. Today people cooperate on vast scales to dominate the world's ecosystems like no other species in the history of life. We are very unusual creatures.

This leads to the obvious question: why are we such unusual animals? People often say that attempts to explain human uniqueness are just vanity, and there is some truth to this. Most of us are more interested in our own evolution than in the evolution of barnacles or baboons. But it isn't *just* vanity. Evolution has been creating vertebrate species for more than 500 million years, and our species is an outlier in comparison with every single one of them. Something very unusual happened during the Pleistocene evolution of our species, and it is of great interest to know what it was. This question gets its bite from the certainty that humans are the products of organic evolution, just like all the other species. As Allen Orr put it: 'Before Darwin, the answer to this question was trivially obvious–because we were nearer to angels than to animals. After Darwin, that answer no longer sufficed, and the question grew more serious, not less' (Orr, 2018, p. 126). So, what happened?

One obvious factor is that we are smarter than other animals. Beginning about 3 million years ago brain sizes in the hominin lineage began to increase, and by 500,000 years ago, hominin encephalization was greater than most other mammals (Kimbel & Villmoare, 2016). There is evidence that humans are better at causal reasoning than other species and this enables us to adjust our behaviour in response to new environments (Bender & Beller, 2019; Vaesen, 2012). This leads to better tools and more productive subsistence techniques allowing us to survive in a wider range of environments. We also seem to be better at theory of mind than other species and it is plausible that this enables us to negotiate more complex, mutually beneficial social arrangements (Vaesen, 2012). According to a number of authors (Barrett et al., 2007; DeVore & Tooby, 1987; Pinker, 2010), these cognitive abilities allow us to adapt flexibly to novel circumstances better than other species. We have entered the *cognitive niche* in which increased intelligence is the key innovation that has made *Homo sapiens* different from other creatures.

It is clear that greater cognitive ability *alone* isn't the answer. Proponents of the cognitive niche see culture as an significant ancillary factor (Barrett et al., 2007). Humans are much better at social learning than other species (Dean et al., 2012). Even in small-scale foraging societies, people depend on tools, foraging techniques, and ecological knowledge that no individual could invent on their own (Boyd et al., 2011; Henrich, 2015). Individuals do not solve most of the problems they need to solve on their own. Instead, human populations accumulate solutions, and our exceptional social learning abilities allow these solutions to spread from one individual to another. According to the proponents of the cognitive niche, culture plays a passive role, preserving adaptations whose fit to the environment is the result of intelligent design.

Pete Richerson, Joe Henrich, and I have argued that proponents of the cognitive niche hypothesis misunderstand the role that culture plays in human adaptation. Sometimes cultural adaptation does involve conscious design based on causal reasoning, but more often it does not. Culture is the key innovation that explains human singularity because it permits the gradual accumulation of adaptations *without* causal understanding, adaptations that were not intelligently designed and no individual in the population understands. Causal cognition plays an ancillary role speeding up the cultural adaption, but it is our entry into the *cultural niche* that is the secret of our success.

The Role of Causal Cognition in Cultural Adaptation

Causal cognition can interact with other processes of cultural change to generate a variety of evolutionary scenarios. These can be arranged on a continuum. At one end, causal reasoning does all the design work. It explains why innovations are adaptive and why they spread. At the other end, causal cognition plays little role. Variation may be generated by attempts to innovate, but these are noisy, and may on average make things worse. When adaptive, innovations spread because people recognize their benefits or because they lead to observable success and people imitate the successful. Here I focus on the two end points of the continuum and a third intermediate point.

Culture as a Library

On this hypothesis, innovations are created using causal reasoning and spread for the same reason. People understand the causal principles that underlie a new practice, and this allows them to mentally simulate different possible innovations and determine whether a new practice is an improvement over the previously used practice. The practice spreads because others understand how the innovation works and why it is an improvement, or because they can observe its beneficial effects and acquire it without understanding why they are beneficial. At this end of the continuum, causal cognition does all of the design work. Innovations are the result of intelligent design. Causal understanding explains why the innovations are beneficial. Culture plays a role because innovation is more costly than social learning and so socially learning allows many to acquire a beneficial innovation at lower average cost.

In this model, social learners are free-riders scrounging valuable information produced by the costly efforts of innovators. In the short run, they increase the average welfare of the population, but in the long run they provide no benefit (Rogers, 1988). Something must be added to the model to reward innovators for their efforts. In models of endogenous technical change used in economics (Romer, 1990) the causal knowledge that underpins an innovation spreads, but innovators are able to exploit their position because patents or trade secrets give them monopoly rents. Alternatively, population structure may limit the spread of the innovation, and small clusters of innovators and imitators to prosper compared to more distant individuals. Finally, social learning allows selective innovation, and so may increase the average fitness (Boyd & Richerson, 1995).

Culture as an Archive of Serendipitous Discoveries

Most of the time, causal knowledge is not sufficient to allow people to design successful innovations, but occasionally the world provides evidence that allows people to do so. People need to be able to make inferences in these especially favourable circumstances, and this may require at least partial causal knowledge. Beneficial innovations spread because people can observe their beneficial effects and acquire them by imitation without understanding why they are beneficial. This scenario is likely to be common because many useful innovations are causally opaque.

Heat treatment of stone may be an example. Tool-makers in several parts of the world improved the knapping properties of stone by burying it in sand under a fire for many hours or by putting it in the cooling embers of a dying fire. Heat treatment is tricky because if the temperature is too high the stone shatters, too low and there is no effect. The rate at which the stone is heated and cooled matters, and all this depends on the kind of stone (Schmidt, 2016). Absent knowledge about the solid-state physics and chemistry of stone, it is hard to see how people could have deduced that heat treatment would work, what temperatures were best, and how to create these temperatures. Instead it seems much more likely that a core was left among the ashes or buried under the campfire by accident, reached the right temperature by chance, and cooled at the right rate, and somebody noticed that the stone was better for knapping. The technique could then be perfected by trial-and-error experimentation, and spread because others recognized that the heat-treated stone made better tools.

Cultural 'Selection'

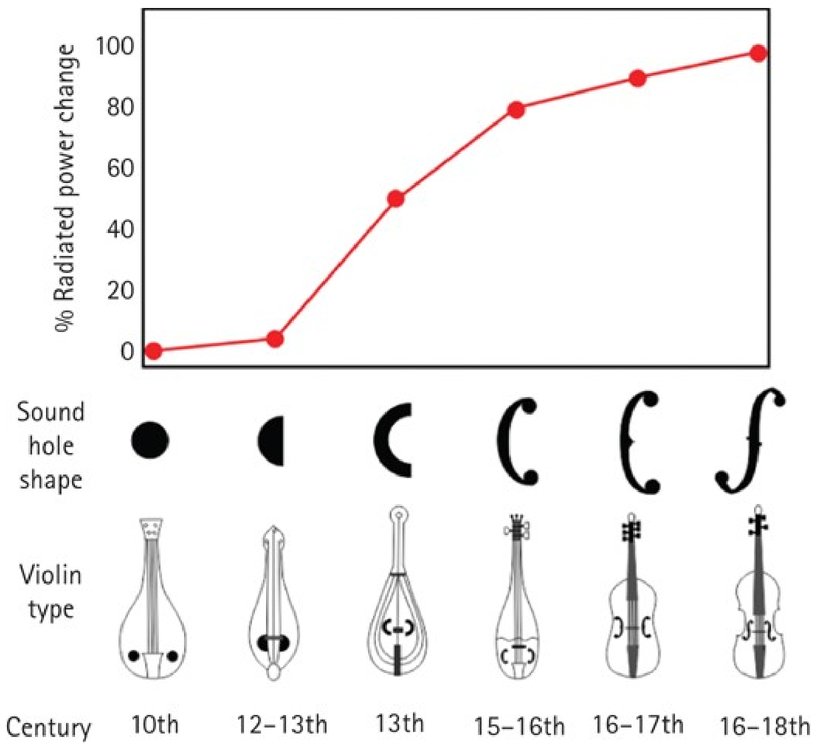
People make trial-and-error modifications of existing practices. These are noisy but need not be completely random. Most trials do not lead to improvements, but causal understandings increase the rate at which beneficial innovations arise. Non-random innovation can lead to the spread of beneficial practices by itself. However, they will spread more quickly if people can recognize that they are better or if they lead to observable success or prestige (Boyd & Richerson, 1985). The first process, guided variation, acts like biased mutation in genetic systems, while the second leads to a selection-like process which depends on the amount of cultural variation.

Sometimes it is argued that cultural evolution is different from genetic evolution because cultural variation is not random (reviewed in Mesoudi, 2021). There is, however, no reason that variation has to be random for selection to operate. In fact, genetic variation is not random with respect to fitness. The vast majority of genetic mutations are deleterious, and this creates a directional pressure that may be important when complex traits are affected by genes at many loci (e.g. Keller & Miller, 2006). This bias is not usually important in genetic evolution because mutation rates are so low. Whether it is important in cultural evolution depends on the rates of cultural innovation and biased imitation. Moreover, if innovations are on average deleterious, biased imitation is necessary for adaptive cultural evolution, just as selection is necessary in genetic evolution (Henrich, 2004; Thompson et al., 2022).

Nonetheless some authors (references in Mesoudi, 2021) believe that cultural innovations result from random errors in replication or performance and these innovations spread because people imitate beneficial innovations. Steve Pinker (1998, p. 209) makes fun of this idea, saying it is as if 'blessed are the peacemakers' gradually evolved through a series of random mistakes and misperceptions to become 'one small step for man, one giant leap for mankind'. He then says: 'I think you will agree that this is not how cultural change works. A complex meme does not arise from the retention of copying errors.' A pithy, memorable example, but notice no evidence, just an appeal to personal incredulity. A number of other authors agree (Fracchia & Lewontin, 1999; Hallpike, 1986; Orr, 2018).

But sometimes the truth is incredible, and there is one well-studied case in which complex functional design seems to have resulted from accumulation of small random copying errors. Nia et al. (2015) studied the evolution of violin design from about 1000 to 1800 CE. It turns out that the sound holes on the top of the violin are by far the most important design element determining its radiated sound power, and that this is proportional the circumference of the holes. This means that long, narrow sound holes are best. In the earliest violins, around 1000 CE, sound holes were round, and over the next 800 years they became longer and narrower, reaching the modern 'f-hole' shape in the late eighteenth century. Most of their data come from a large sample of violins made in the workshops of violin makers (including Stradivarius) who lived in the Italian city of Cremona from about 1565 to 1775. The rates at which the sound holes change shape is consistent with a model in which violin-makers made small random manufacturing errors, and then selected the best-sounding violins to copy. There is no evidence for planned change in sound hole design during this period. However, in the early nineteenth century, two designers made conscious efforts to create better designs. Both were failures because both designers chose sound holes that were shorter and wider than those in classical Cremonese violins, and as a result radiated power fell to fifteenth-century levels, much lower than that of designs that resulted from the accumulation of random errors. This natural experiment suggests that Cremonese violin-makers did not have a causal understanding of sound hole design (Figure 1)

Figure 1



Changes in radiated power in European violins and sound hold shape over time. From the tenth century through the eighteenth century sound holes changed shape, and this resulted in greater radiated power. Radiated power increases with the length of the perimeter of the sound hole.

(Redrawn from Nia et al., 2015.)

Empirical Data on Causal Understanding and Cultural Adaptation

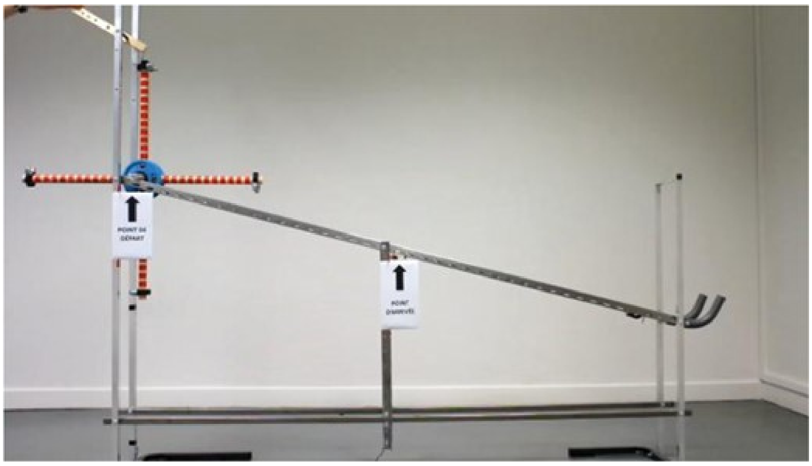
Two recent empirical studies suggest that adaptive designs can evolve without learners understanding important trade-offs that are entailed in those designs.

The 'Wheel Experiment'

A recent experiment by Maxime Derex and co-authors (Derex et al., 2019) shows that cumulative cultural change can occur in an experimental setting without an accompanying increase in causal understanding. Experimental participants were shown a wheel with four spokes, and on each spoke, there was an adjustable weight (Figure 2). Participants were tasked with arranging the weights so that the wheel rolled down a 1 metre-long ramp in the shortest possible time. This task is tricky because two competing physical principles are at work. You want to minimize the moment of inertia so that the wheel accelerates more quickly in response to the force of gravity. This means moving the weights close to the hub. However, you also want to maximize the initial potential energy, and this means moving the top weight as high as possible. The time-minimizing arrangement is to place the top weight up about 40 per cent of the length of the spoke and the rest as close as possible to the hub. As tricky as this problem is, it is much, much simpler than the design problems entailed by technologies like bows and kayaks that are essential for life in small-scale societies.

Twenty-eight groups of five participants were arranged in transmission chains. Each participant got five trials. During each trial they could adjust the weights, and observe how long it would take for the wheel to descend. The first person had to solve the problem on their own, but the remaining participants got information from the previous person in the chain. There were two treatments. In the ‘configurations’ treatment, participants were provided with the configuration of the weights used in the previous participant’s last two trials and the associated scores. In the ‘configurations + theory’ treatment, participants observed the configurations and scores of the individual who preceded them in the chain, and were provided with a brief statement written by the preceding participant explaining why they chose the configuration they did. Monetary rewards were based on the participant’s own performance on their last two trials and that of the next person in the chain. After their five trials participants were given a test that measured how well they understood the two causal principles worked.

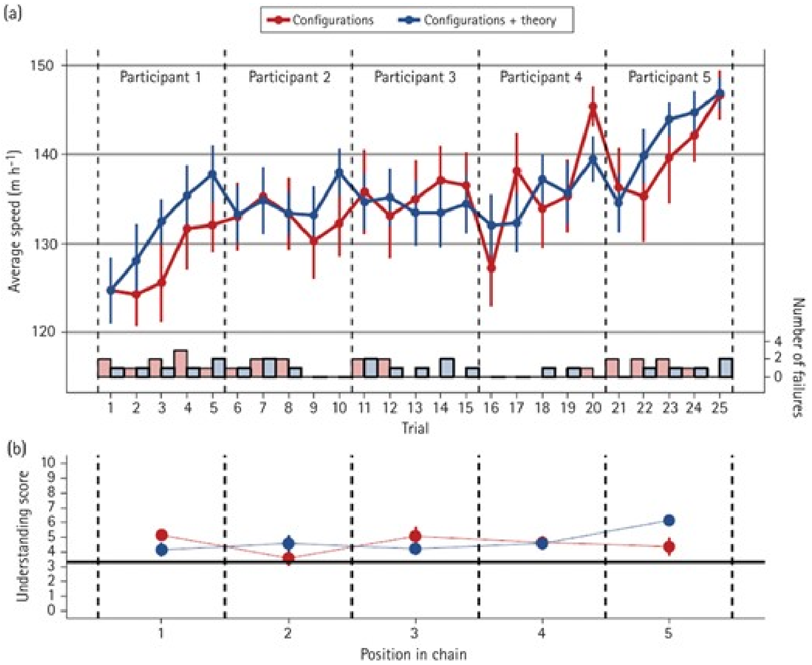
Figure 2



The experimental set up used in the Derex et al. (2019) experiment (used with permission). The wheel has four spokes each with an adjustable weight. The problem was to adjust the weight to minimize the time it took for the wheel to travel one metre down the ramp.

In both conditions, participants got much better at arranging the weights over the five generations of the transmission chain, but in neither condition did their causal understanding increase (Figure 3). Participants learned how to configure the wheel to make it go faster, and over only four cultural generations improved to within 70 per cent of the best possible configuration, on average. They started with a bit of causal understanding, but despite the opportunity to experiment and observe the results, participants had no better causal understanding at the end of the transmission chain that at the beginning. Interestingly, transmitting a verbal theory did not significantly affect the average performance but it did affect how participants learned. A lot of the theories were just nonsense, but some articulated causal explanations that encoded one of the two principles. These theories affected the participant’s behaviour. People who received a moment of inertia theory placed the weights closer to the hub, and those that receive a potential energy theory tended to raise the upper weight. You would think that this would increase the performance in the configuration + theory treatment. But it didn’t because receiving a theory reduced exploration of alternative configurations so that participants in the configuration + theory treatment didn’t do any better than those who only observed behaviour.

Figure 3



(a) The average speed of the wheel increases over time as participants learn from the previous participant, experiment, and serve as models for the next participant. (b) The scores on a quiz measuring participants' understanding of the mechanics of the wheel do not increase.

(From Derex et al., 2019.)

It is important to see that this experiment precludes any biased imitation. Each individual observes only one model and so cannot compare the performance of wheels generated by different participants. Biased imitation plays a big role increasing performance in experiments in which it is possible (e.g. Derex & Boyd, 2015; Thompson et al., 2022).

Causal Understanding among Hadza Bowyers

Experiments are very important because they allow control of participant's motivations and the information they have available. However, they also suffer important limitations. Inventing the practices and tools that are essential for life in small-scale societies is typically much more difficult than solving the problems posed in laboratory experiments, and the stakes and therefore the penalties for failure are much greater. In the laboratory participants are asked to adjust weights on a wheel or build towers using spaghetti and modelling clay (Caldwell & Millen, 2008). Compare these to inventing a method for detoxifying cassava (Henrich, 2015) or constructing a working kayak (Heath, 1991). Such problems cannot be solved on laboratory timescales, and inadequate solutions can be fatal. It would be of great interest to measure the role of causal knowledge in an important technology used by people living in the sort of small-scale, face-to-face societies in which people have lived for most of their history.

Jacob Harris and colleagues (Harris et al., 2021) measured the extent of causal understanding of bow mechanics among the Hadza, one of the world's few remaining foraging groups. The Hadza hunt large game like zebra and wildebeest using bows that men manufacture from wood and sinew, and might make 100 over their lifetime. Hunting is important for subsistence and male prestige.

Harris et al. (2021) define causal knowledge as the ability to predict the effect of an intentional modification of a system. For example, bows vary in the cross-sectional profile of their limbs. Hadza bows have a round cross-section, but foragers elsewhere made bows with flattened cross-sections (Grayson et al., 2007; Pope, 1918). Changing the cross-sectional shape affects important aspects of bow performance like energy storage and draw weight. A bowyer has causal knowledge if he can predict the effects of changing the cross-section. All other things equal, bows with a flat cross-section store more energy than bows with a round cross-section (Baker, 1992), resulting in more range and killing power. Of course, many other factors could figure into the choice of bow design. A bowyer who understands that a flat cross-section leads to more power than a round one might still choose to make a bow with a round cross-section because the benefits of increased power are less than the costs in terms of, for example, difficulty of manufacture. If this were the case, causal knowledge plus a desire to make a useful bow, explains the choice of bow design. If, however, the bowyer does not know the effects of changing cross-section, the costs and benefits of changing cross-section cannot be balanced against other effects and, assuming that range and killing power are important, causal knowledge does not explain bow design.

As part of a lengthy interview about bows, Harris and colleagues asked Hadza bowyers 13 multiple choice questions about bow mechanics divided into two types. *Design* questions focused on choices made by the bowyer during manufacture that affect the shape of the bow. For example, participants were asked whether a round or flat cross-section would make the arrow go faster. *Mechanical* questions focused on factors associated with the use of the bow. For example, they were asked, does increasing the draw weight make the arrow go faster? Participants performed better than chance on four out of five mechanical questions, but only three of nine design questions. Moreover, for four of the eight design questions participants shared beliefs about bow design that reflect a systematic misunderstanding of cause-and-effect knowledge. For example, Hadza bowyers unanimously expressed beliefs about limb cross-sections that diverge from what is known about bow mechanics. Experimental studies in bowyer mechanics suggest that limbs that are flatter and more rectangular are more energy efficient than other designs (Baker, 1992; Klopsteg, 1943). Despite being aware of other design options most bowyers indicated that any deviation from a bow with the round-shaped cross-section would result in a deleterious outcome. This in turn suggests that Hadza bowyer's choice of cross-section shape is not the result of a causal understanding of the efficiency of alternative shapes.

The lack of causal understanding does not mean that Hadza bows are poorly designed. Hadza bowyers manufacture high-performance bows capable of killing a wide variety of prey using materials available in the local environment. There are many trade-offs in bow design, and Harris and his colleagues measured knowledge relevant to only a few. A round cross-section could be better because materials are more readily available, because it is easier to manufacture, because it is more durable, because it is less likely to fail, or other factors currently unknown to us. The fact that the Hadza do not understand some trade-offs does not imply that their bows are suboptimal. A bow with a rectangular cross-section or a reflexed profile might generate more arrow speed but be too time-consuming to make or perhaps too fragile. It is a mistake to think that individual calculations based on causal understanding must yield better solutions than cultural learning. Individual learning and calculation can be costly and error prone, and it may often be better to adopt the solutions arrived at by your culture over time. There is much theory that suggests that this is possible and it is this conviction that stands behind the hypothesis that it is cumulative cultural evolution that has allowed our species to be so successful over the last 50,000 years.

What is a Key Innovation?

There is no doubt that cumulative cultural evolution *and* increased cognitive ability played crucial roles in making humans such odd creatures. The debate is about the relative importance of these factors. According to the cognitive niche hypothesis, people, and only people, evolved improvisational intelligence, 'the computational ability to improvise solutions in developmental time to evolutionarily novel problems' (Barrett et al., 2007), and this enables them invent new, highly adaptive tools and practices. Culture plays a role because it allows others to share beneficial innovations. Inventors are like authors, slaving over drafts to make them perfect. Culture is just the library in which the books are stored. According to the cultural niche hypothesis, people have evolved cognitive and motivational systems that allow human populations gradually to accumulate and transmit adaptive tools and practices that no-one in the population fully understands. They are motivated to adopt the behaviour of others and are equipped with social learning mechanisms like attend to the most common behaviour and attend to the behaviours of successful people, and these systems give rise to cumulative cultural adaptation. Innovations matter, and greater intelligence aids this process, but by itself is woefully insufficient. The cognitive and motivational systems that give rise to cumulative cultural evolution are the key innovations that have made our species so successful.

By claiming that cumulative cultural adaptation was the key innovation that gave rise to human uniqueness, I mean that it was the most important innovation. I mean that it is the difference that made a difference. Everything followed from this change.

An example from a different technological realm may help clarify what I mean. When I was an undergraduate, I learned to program in FORTRAN IV on the university mainframe, a CDC 3600, one of the most powerful computers available in the mid-1960s. It cost about $10 million in 2021 dollars. The central processing unit (CPU) was based on discrete transistors. It ran at about 1 MHz, and the 192 kilobytes of memory was based on ferrite cores, little metallic donuts strung on an array of wires, each donut encoding one bit. It occupied a large, air-conditioned room in the basement of the Natural Sciences Building. Programming was time-consuming and, for the novice programmer, often humiliating. You would write out your program on a deck of punched cards and hand it in to the people behind the desk. A day later you would come back and pick up the output, with syntax errors listed as obscure numerical codes, or worse, pages of nonsense there for everybody to see.

These days I still do some coding. I use a Dell XPS 13 laptop and program in MATLAB. The XPS 13 is a nice little laptop but it is a long, long way from the supercomputers of 2021. It cost about $1,000. The CPU is based on an Intel I5 microprocessor that operates at 4 GHz, more than 1,000 times faster than the 3600. It has 16 gigabytes of memory, about 100,000 times more than the 3600, also based on integrated circuits. It weighs a bit less than three pounds and I can carry it around, no problem. Programming using an interpreted language like MATLAB with an interactive debugger is a joy compared to the old days. I still make stupid coding errors but now they are rapidly fixed and only I know about them. It also serves as my word processor, entertainment centre, and connects me to the internet anywhere there is Wi-Fi.

So, how do we explain this incredible progress? Computers are complicated objects with many attributes. Many are very different today, but many are very similar. It is tempting to say that many advances have been important. However, I think most people would agree that the key innovation was the integrated circuit because everything else followed from that change. Shrinking transistors and other circuit elements allowed microprocessors like the I5 that have a billion transistors on a flake of silicon the size of a fingernail. RAM chips have about one transistor per bit, or 128 billion for my XPS 13. Large numbers and small size mean low cost and low power consumption. Of course, lots of other things have changed too: input and output go through an LCD screen, modern languages are much higher level than FORTRAN IV, and operating systems have become much more complex, and many of these changes are essential for construction of a modern laptop. But there is an important sense in which all of these changes are the result of the evolution of integrated circuit technologies. It was the key innovation among many.

According to the cultural niche hypothesis, cognitive and motivational systems that give rise to cumulative culture were the key innovation in the evolution of the human lineage. Culture allows the accumulation of culturally transmitted adaptations to local environments, different tools, foraging practices, ecological knowledge, and social norms, suited to different environments. People now have larger brains, are better at causal reasoning, and have more flexible social behaviours than other primates, and these changes enhance the human ability to adapt better to local conditions. But these improvements were made possible by cumulative cultural evolution in the same way that the higher-level languages and complex operating systems of contemporary computers were made possible by integrated circuit technology. The ability to accumulate and store knowledge over generations favoured the evolution of larger brains and enhanced cognitive ability because it provided people with more data to compute on. Cumulative culture allowed groups in different environments to evolve and maintain norms that were well-suited to those environments. Over the last few hundred years, the exponential growth of scientific knowledge and the division of labour made possible by large, complex well-regulated societies has made conscious design more important, skewing our intuitions about innovation. But on evolutionary timescales, cumulative culture was the key innovation.

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