

What makes us smart?

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Abstract

How did humans become clever enough to live in nearly every major ecosystem on earth, create vaccines against deadly plagues, explore the oceans depths, and routinely traverse the globe at 30,000 feet in aluminum tubes while nibbling on roasted almonds? Drawing on recent developments in our understanding of human evolution, we consider what makes us distinctively smarter than other animals. Contrary to conventional wisdom, human brilliance emerges not from our innate brainpower or raw computational capacities, but from the sharing of information in communities and networks over generations. We review how larger, more diverse, and more optimally interconnected networks of minds give rise to faster innovation and how the cognitive products of this cumulative cultural evolutionary process feedback to make us individually ‘smarter’—in the sense of being better at meeting the challenges and problems posed by our societies and socio-ecologies. Here, we consider not only how cultural evolution supplies us with ‘thinking tools’ (like counting systems and fractions) but also how it has shaped our ontologies (e.g., do germs and witches exist?) and epistemologies, including our notions of what constitutes a ‘good reason’ or ‘good evidence’ (e.g., are dreams a source of evidence?). Building on this, we consider how cultural evolution has organized and distributed cultural knowledge and cognitive tasks among subpopulations, effectively shifting both thinking and production to the level of the community, population or network, resulting in collective information processing and group decisions. Cultural evolution can turn mindless mobs into wise crowds by facilitating and constraining cognition through a wide variety of epistemic institutions—political, legal and scientific. These institutions process information and aid better decision-making by suppressing or encouraging the use of different cultural epistemologies and ontologies.

Most researchers who have addressed the question of human creativity and intelligence are culturally WEIRD, meaning they grew up or were educated in societies that are Western, Educated, Industrialized, Rich and Democratic. Although people from diverse societies attribute technologies to ancient ancestors and both Chinese and American participants believe they have a better understanding merely because someone in their group knows more (Fullerton et al., 2020; Sloman & Rabb, 2016), not all societies focus so much on individual attributes, ascriptions, accomplishments and mental life. For example, in some societies, speculation about mental states is taboo and moral culpability is a result of actions alone rather than both actions and mental states (Barrett et al., 2016; McNamara et al., 2019), and in general people in WEIRD societies make more dispositional attributions (Choi et al., 1999; Na & Kitayama, 2011). This WEIRD inclination toward individualism, dispositionalism and analytic thinking (Henrich, 2020) leads many researchers to intuitively perceive individuals as autonomous and independent decision-makers endowed with properties or dispositions—abilities (“genius”), personalities (“hard worker”), attitudes, genes (for dispositions or abilities, such as IQ) and preferences—that account for their behavioral and psychological phenotypes. Further, unlike more holistic thinkers who focus on people’s relationships, most cognitive scientists are potent analytic thinkers who tend to tackle problems—at least initially—by breaking complex systems down into their constituent parts and assigning them properties. If a person is creative, we break her thinking down into its cognitive and motivational processes to figure out how these may explain her creativity. If a society is innovative, the inclination is often to break the group down into individuals and assess the creativity of each member. This tendency may be strongest among those trained in psychology, which may be the WEIRDest scientific discipline (May, 1997).

This quest, to identify the “innovators,” pervades both popular culture and scholarship, giving rise to what historians have dubbed “the myth of the heroic inventor” (Basalla, 1988; Mokyr, 1990)—an extension of Carlyle’s “Great Man” theory of history. WEIRD people tend to see inventions as the creative products of geniuses who, through their own personal fortitude and solitary perspiration, take great leaps forward. Of course, as detailed studies make clear, new inventions, fresh insights and novel ideas involve incremental steps that recombine—often through a healthy dose of serendipity—existing ideas, technologies, observations and concepts (Ridley, 2020; Sneader, 2005; Williams, 1987). Typically, the key elements are already circulating within some community or social network, waiting for assembly. The near ubiquity of multiple invention—e.g., calculus, radio, telephone, AC current, natural selection and relative time—attests to the centrality of the social network and accumulation of circulating elements over the criticality of *singular* geniuses (Merton, 2013; Simonton, 1979).

Perpetuating this focus on the individual, both cognitive psychology and neuroscience suffers from what we might call the “myth of the heroic brain.” This “Great Brain” theory of innovation implicitly or explicitly assumes that what makes us smart and creative are the innate algorithms or raw processing powers of individual brains. Consequently, different researchers variously argue over the secret of great brains—the powers of rationality, reasoning, mental models, frugal heuristics and Bayesian computational abilities (Gershman, 2021; Gigerenzer et al., 1999; Gigerenzer & Goldstein, 1996; Herculano-Houzel, 2016; Mercier, 2017). By such accounts, we engineer powerful rocket engines, construct vast suspension bridges, craft stunning sculptures, design new vaccines and compose sophisticated sonatas because “some person knuckles down, racks his brain, musters his ingenuity, and composes or writes or paints or invents something.” (Pinker, 1997: 97), to quote one renowned cognitive scientist on how (he suspects) innovation happens.

Curiously, “Great Brain” theories of human innovation flourish despite well-established countervailing trends. Researchers in the psychological and economic sciences have long critiqued the assumption that decision-makers are rational, taking in and evaluating information on the costs and benefits of alternative options (Kahneman, 2011; Nisbett & Ross, 1980; Tversky & Kahneman, 1973)—though see Gershman (2021) on the Bayesian origins of such biases. A dive into this literature leaves one feeling hopeless. We humans (well, this research is done almost exclusively with WEIRD people, but that’s a separate issue) appear to be complete morons: our reasoning is riddled with irrationalities, our perceptions are illusory, our judgments flawed in dozens of ways and when we do seek information, we take biased, small samples that mostly confirm our existing beliefs. Compounding these flaws, we suffer from a blindness to our own biases (Pronin et al., 2002) and an illusion that we understand the world better than we do (Keil, 2003; Sloman & Fernbach, 2017). One might resolve this conflict by suggesting that the great geniuses represent those few who managed to escape these irrational biases, but the history of incredibly bad ideas supported by these exalted minds, not to mention the prevalence of multiple invention, suggests this is unlikely to resolve matters. So, how can we explain human creativity, technical innovation and artistic flourishing, not to mention the immense ecological success of our species (Henrich, 2002)?

Here, taking a broader perspective, we deploy an evolutionary approach to humans as a cultural species that integrates a diverse body of research from different disciplines including those under rubrics such as “the extended mind” (Clark & Chalmers, 1998), “collective intelligence” (Engel et al., 2015; Woolley et al., 2010), “community-of-knowledge” (Sloman & Rabb, 2016), “cultural intelligence” (van Schaik & Burkart, 2011) and “distributed cognition” (Hollan et al., 2000). Here, we explain how this collective brain evolved and how it shapes, sharpens and distributes the cognitive abilities of each of its constituent brains. To do this, we draw on the Cultural Brain Hypothesis (Boyd, 2017; Henrich, 2016; Laland, 2017; Muthukrishna et al., 2018; Muthukrishna & Henrich, 2016; Street et al., 2017). Humans, to a degree not seen in other species, rely on a massive body of accumulated cultural information to survive and thrive, even in the harsh hunter-gatherer environments that characterized the last two million years of our evolutionary history. As evolved cultural learners, individuals adapt to their worlds not by figuring it out anew each generation, but by primarily learning from others, especially earlier generations. This information includes motivations, beliefs, skills, know-how, heuristics, (over)confidence, emotional reactions, decision heuristics and attentional biases.

Computational modeling of the Cultural Brain Hypotheses (Muthukrishna et al., 2018) illustrates how brain size, life history and the corpus of adaptive cultural knowledge can coevolve, driven by the autocatalytic interaction of genes and culture. As the cost of larger brains grew in terms of calorie requirements and challenges to birthing a big-brained baby, human life histories evolved to support an ever-growing cumulative cultural corpus. Gestation grew shorter, childhood extended, and menopause evolved, all driven by the selection pressures created by an ever-expanding body of adaptive cultural information capable of delivering fitness benefits to those capable of acquiring, storing, organizing, applying and retransmitting this information (Kendal et al., 2018; Tomasello, 1999; Tomasello et al., 1993). The resulting increase of 56 billion neurons over about 2 million years were ‘for’—from natural selection’s perspective—learning from and transmitting to others, not for individually solving problems. These neural and life history changes were alone insufficient to store the ever-expanding body of knowledge, leading eventually to a division of information and labor (Migliano & Vinicius, 2022) and collective computation (Chater, 2022; Hollan et al., 2000; Hutchins, 1995). Crucially, our collective brains

involve not just what we might normally think of as the elements of culture—tools, techniques, approaches, recipes, beliefs and values—but also how we think and what we think about. That is, cultural evolution within collective brains rewrote our brains’ software, giving us new ways of thinking, which ultimately made us cleverer (Dennett, 2009, 2017; Sterelny, 2012). Below, we highlight and summarize four insights that arise from the Cultural and Collective Brain Hypotheses:

- 1) Innovation and cumulative cultural evolution depend heavily on the size, interconnectedness and diversity of a population’s or network’s collective brain.
- 2) Individual smartness, or the ability of individuals to solve locally relevant problems, depends on the products of cumulative cultural evolution and thus on the collective brain.
- 3) With the rise of distributed cognition and an informational division of labor as well as the challenge of increasingly diverse problems, cultural evolutionary incentives favor effective problem-solving in small groups and at scale. The problem-solving abilities of groups depend heavily on their cognitive diversity and social psychology as well as a wide range of interactional, organizational and epistemological norms.
- 4) Collective decision-making—the ability of groups to make smart decisions—depends on culturally-evolved norms that govern the interactions among individuals and subgroups as well as the selection of leaders.

This approach, with its focus on the selection pressures created by the interaction of cultural evolution and the environment, integrates a version of the Social Brain Hypothesis (Humphrey, 1976) with the Ecological Intelligence Hypothesis (Rosati, 2017). The approach considers different selection pressures than theories rooted in managing social relationships (Dunbar, 1993) and Machiavellian strategizing (Whiten & Byrne, 1997) as well as offering a distinctive set of predictions that partially overlap with these other hypotheses (Baimel et al., 2021).

Let’s consider each of these insights.

Collective brains drive innovation

Based on a class of formal cultural evolutionary models (Creanza et al., 2017; Henrich, 2004; Kolodny et al., 2015; Lehmann et al., 2010; Mesoudi, 2011; Powell et al., 2009), the ability of communities—or collective brains—to innovate depends on: (1) the size of the community of potential innovators, (2) their social interconnectedness or subpopulation structure, (3) cultural transmission technologies and tendencies, and (4) their cognitive diversity. Below, we sketch each prediction and the current evidence.

First, both population size and the social interconnectedness of individuals should have a substantial influence on the rate of innovation and the steady-state level of cultural complexity, which includes technical know-how, linguistic repertoires, recipes and other aspects of culture. *Ceteris paribus*, populations with more individuals are both more likely to generate new ideas, whether through serendipity, insight or some combination, and better able to resist the chance loss of rare domains of know-how, experience, expertise or arcane forms of cultural knowledge (which may be, or become, important). Such losses may remove not only useful or clearly recognized know-how from a population, but can also involve the disappearance of seemingly unproductive elements that nevertheless reduce the population’s ability to adapt to future conditions by, for example, providing an essential ingredient for a future recombinant innovation. Crucially, from the point of view of the individual, the *same person*

will appear more creative when they live in a larger population or network. Broadly, a large body of both observational and experimental evidence supports the power of population size.

Unlike population size, where generally bigger is better, there is an optimal level of social interconnectedness that maximizes both the rate of innovation and the steady-state level of cultural complexity (Campbell et al., 2022; Derex et al., 2018; Derex & Boyd, 2016; Schimmelpfennig et al., 2022). In most historical contexts, greater interconnectedness has favored faster cumulative cultural evolution and higher levels of stable cultural complexity. Greater connectivity among diverse minds in these situations creates more opportunities for ideas to interact and generate novel recombinations (Creanza et al., 2017; Kolodny et al., 2015; Lewis & Laland, 2012). Because the nature of cultural evolution and cooperation means that growing populations tend to fragment and fractionate (Henrich, 2016), the challenge that has confronted most societies and organizations has been staying socially connected and cooperative.

Nevertheless, both theoretical and experimental research suggest that too much interconnection can reduce the rate of cumulative cultural evolution, thus slowing innovation (Derex et al., 2018; Derex & Boyd, 2016; Migliano et al., 2020; Schimmelpfennig et al., 2022). This arises for a couple of interrelated reasons. First, many problems have multiple solutions, each of which can only be obtained by following a different cultural evolutionary pathway involving gradual, cumulative innovations or modifications. Once perfected, or at least substantially improved, these different approaches may vary in their effectiveness and overall desirability. Second, if populations aren't too interconnected, different solutions may emerge and undergo at least some independent development and improvement. This "let a thousand flowers bloom" approach allows multiple solutions to compete on a more equal footing, which increases the chances that the best long-run solution will be found. However, if a population is too interconnected, an inferior solution may spread widely very quickly and undergo rapid improvement. Even if someone discovers an alternative pathway that may eventually lead to a superior solution, the early versions of most efforts will often be inferior to the much-improved version of the first pathway explored. Thus, populations that are too interconnected can get stuck on suboptimal solutions. The electric car, for example, was invented in the 19th century and represented over one-third of cars manufactured in the US in 1900 (Martin, n.d.; Standage, 2021). But, in 1908, Henry Ford delivered the Model T, which crushed the competition on both price and range (before refueling). As a result, electric cars largely vanished from American roads for a century, Americans went up a suboptimal and ultimately dangerous peak—as recent developments in electric cars illustrates. Beyond the impact of multiple solutions, too much interconnectedness may reduce a population's overall cultural diversity, which reduces the ambient levels of variation that provide ingredients for novel recombinations. As with population size, the creativity or innovativeness of individuals depends on the social network or community they reside within.

Technologies and institutions that evolved for cultural transmission, such as schools (Ritchie & Tucker-Drob, 2018), Sesame Street (Kearney & Levine, 2019), and perhaps the Internet/social media (Parise et al., 2015), are all ways of potentially transmitting some ideas more effectively and particular types of cognitive skills, ranging from reading, writing and arithmetic to self-regulation, temporal discounting and argumentation. Formal education in particular is an efficient tool for transmitting a culturally-evolved corpus to young humans, preparing them to take part in and succeed in the adult worlds of their societies (Ritchie & Tucker-Drob, 2018).

Finally, because most innovations are recombinations (Thagard, 1998; Youn et al., 2015), a population's cognitive diversity supplies crucial fuel for the fires of creativity. Here, cognitive diversity includes domains of knowledge and expertise as well as ways of thinking, feeling and perceiving—i.e., information processing. Cognitive differences arise from many sources, including languages, cultural backgrounds, personal experiences, formal training and genetic endowments. Differences in sound perception, for example, are influenced by both musical training and fluency in a tonal language like Mandarin or Zapotec (Blasi et al., 2022). Social interactions among cognitively diverse individuals increase the chances of novel recombinations and serendipitous insights (Page et al., 2019).

A large body of ethno-historical, experimental and observational evidence support the predictions derived from the collective brain. For example, by combining U.S. patent data with Census data from 1880 to 1940, Winkler et. al. show not only that more populous counties produce more innovations per capita but that this effect further increases in more cognitively diverse counties (Winkler et al., n.d.). Here, the results hold whether “innovations” are measured using (1) simply patents per capita or (3) breakthrough patents per capita derived by analyzing the introduction of novel concepts. As a proxy for cognitive diversity, the authors used surnames, showing how they capture variation in cultural background, family traditions and occupational differences, among other elements of diversity. To confirm that the effects are driven by diversity, the authors compare people with the same surname who live in counties with varying levels of diversity. The results show that bearers of the same surname are more innovative—produce more patents—when they live in more diverse counties.

To go beyond these correlational results, Winkler and colleagues also identify quasi-experimental random variation by looking at the effects of immigration. For idiosyncratic reasons, such as famines in Eurasia and the laying of railroad tracks near some American towns (but not others), immigrants are more likely to arrive in some U.S. counties over others in ways that vary over time. The results reveal that immigration drives innovation by increasing a county's cognitive (surname) diversity. Notably, larger inflows of immigrants increase the patenting activity of native-born individuals in these counties, making them more creative. These results confirm, and inform, a growing body of evidence showing how immigration has propelled innovation over U.S. history and that this has consistently increased the innovativeness of native-born Americans (Akcigit et al., 2017; Burchardi et al., 2021; Nunn et al., 2017; Sequeira et al., 2020).

The powerful effects of immigration on innovation were starkly observed with the enactment of the Johnson-Reed Act (1924), which limited immigration from Eastern and Southern Europe (Moser & San, 2020). After 1924, patenting dropped by two-thirds across the 36 fields in which Eastern Europeans had made contributions prior to 1924—fields like radiation, radio and polymers. Without this influx of new ideas, native-born Americans became less creative, experiencing a 62% decline in patenting. A decade after President Johnson had ended these quotas in 1964, U.S. innovation was again fueled by immigrants coming from Mexico, China, Vietnam and the Philippines (Burchardi et al., 2019).

The collective brain makes sense of another well-established pattern: larger U.S. cities and more interconnected counties—via transportation infrastructure—produce disproportionately more innovations per capita (Bettencourt et al., 2007, 2010). The rate of patenting per person in U.S. counties doubles in the two decades after the arrival of train lines, wiring these counties into America's collective brain (Perlman, n.d.).

Under more controlled laboratory conditions, the role of population size and interconnectedness has now been tested in several laboratory experiments where researchers have explored and compared the role of specific mechanisms. These experiments often exploit in-lab cultural transmission chains. In one battery of experiments, researchers kept population size constant but adjusted interconnectivity. Participants in the treatment condition with access to more “teachers” from the previous generation maintained higher skill levels in a series of rock-climbing knots and better learned to use the Gimp photo-editing tool to replicate a complex target image. Both the more-connected and less-connected treatments had their naturally gifted knot-tiers and photo editors, but only those in the connected condition could improve upon the previous generation’s best efforts. Further analyses of the transmission patterns of specific elements in the task revealed that interconnected participants were strategically learning from the best performers in the previous generation, recombining different elements they got correct or were more adept at teaching. In the final generation, the worst performing participant in the more-connected condition was better than the best performing participant in the less-connected condition (Muthukrishna et al., 2014)—illustrating how the collective brain dominates any differences among individual brains. Complementary experiments show that larger groups similarly result in more innovation and greater cultural accumulation (Derex et al., 2013; Kempe & Mesoudi, 2014) and that partially connected populations structured into subgroups can outperform fully connected groups (Derex & Boyd, 2016). Taken together, these experiments illustrate how the collective brain dominates any differences among individual brains. After only 10 laboratory generations, all individuals from groups with larger collective brains can outperform every individual from groups with smaller collective brains.

The evidence presented above reveals how living in larger, more diverse and optimally interconnected populations can make individuals more creative and innovative. But can the collective brain and cumulative cultural evolution make them better at problem solving independent of these social or network factors?

Collective brains make us individually smarter

Faster cumulative cultural evolution, fueled by larger collective brains, can make individuals smarter in the sense of being better able to tackle the *novel* problems posed by their societies and environments. This occurs in several different ways, many of which haven’t been studied in detail.

Perhaps the clearest and most obvious way is by supplying individuals with concrete cultural products that embody or distill both specific solutions and general concepts that can be re-deployed and recombined to produce innovations. Over the course of human history, for example, technologies involving wheels, pulleys, levers, wedges and screws have evolved culturally and spread. Each of these was initially hard to invent (rarely thought of), but once invented, both the application and the underlying concept became easier to learn (from a working exemplar) and re-deployed in novel ways. The wheel, for example, appears to have only been invented once in human history, and only in Eurasia. Initially, wheels were used for carts and pottery, but later the concept was applied to mills, clocks and industrial machines (Henrich, 2016).

Beyond concepts that can be embedded in physical technologies like screws, cumulative culture and collective brains have also generated mathematical tools and concepts, beginning with numbers themselves. Societies vary from lacking discrete integers (neither words nor sharp concepts) to

possessing systems that permit them to count without bound. Many societies, for example, traditionally counted “1, 2, 3, many”, lacking any discrete integers above 3. Others used body parts systems to variously count to 10, 12, 17 and 28. Comparative psychological research suggests that the habitual use of particular practices or customs can foster the development of novel numerical abilities that distinguish humans from other animals (Bender & Beller, 2012; Gordon, 2005; Overmann, 2015; Pica et al., 2004).

As societies scaled up, some added written representations of numbers, which variously took advantage of different bases (2, 10, 12), place values (the “2” in “21” represents 20) and a number symbol for nothing (“0”). Today, essentially all societies have adopted Hindu-Arabic numbers, which largely developed in India, spread to Persia, entered the Islamic world, and finally penetrated Europe, where elites resisted both “Arabic” numbers and the zero symbol (Seife, 2000; Starr, 2015).

Numeracy, like literacy, is a culturally-evolved cognitive-upgrade that gives us new mental capacities. Cumulative cultural evolution operating over thousands of years has gradually produced a growing list of concepts and techniques for dealing with actual and symbolic quantities, including addition, subtraction, division, multiplication, fractions, decimals, powers, equations, algebra, logarithms, geometry, probabilities and many more (Bose, 2018). These cognitive tools allow even elementary school children to readily conceptualize and solve all manner of problems that would have seemed impossible to the smartest people in earlier societies.

Cumulative cultural evolution has also shaped our perception (Yoon et al., 2014). Consider color: while some small-scale societies have 0 or 2 abstract (basic) color terms, like extensive versions of ‘black’ and ‘white’, many larger scale societies have over 10 such basic color terms. Recent evidence suggests that speakers of languages with labels that distinguish color terms can more easily highlight fine grained distinctions. Not surprisingly, people are better at distinguishing shades that are labelled with different terms in their language, but worse at distinguishing shaded groups under the same label (Allred & Flombaum, 2014; Deutscher, 2011). Russians, for example, have different words for lighter blues (“goluboy”) and darker blues (“siniy”). English has no such distinction. Russian speakers were faster at discriminating these two colors compared to English speakers with larger effects where the colors presented were perceptually closer (Winawer et al., 2007). Exploiting a parallel terminological distinction in Greek using event-related potentials (ERP), Thierry et. al. (2009) show distinct automatic, preattentive neurological responses to linguistically-marked shades of blue (but not unmarked shades of green) in Greek speakers but not English speakers. The results indicate that the brains of Greek speakers reacted automatically in a non-linguistic task to pattern deviations marked in their language while English speakers did not.

Unlike in our industrialized world where control over pigments can offer identical shirts in a spectrum of colors, in foraging societies, color rarely uniquely marks crucial distinctions. Olfaction, however, plays a larger and more important role. Recent work among foraging populations in Bolivia and Malaysia reveals that these populations possess both richer vocabularies for describing scents, deploying a large number of basic olfactory terms, and are superior at identifying odors (Majid & Kruspe, 2018; Sorokowska et al., 2013).

These patterns are consistent with evolutionary approaches arguing that our brains have evolved genetically to adapt ontogenetically to hone our cognitive abilities, responding to the social, technological and institutional incentives and prestige hierarchies of our societies (Henrich, 2016; Heyes,

2018). To prepare individuals, cumulative cultural evolution has shaped children's games, schooling institutions and the routines of daily life in ways that cultivate the cognitive skills that promote success in particular societies. For example, in many small-scale societies, foraging forays away from the community foster the development of skills in spatial navigation that permit children to safely travel through forests, woodlands and deserts. The development of these abilities are often reduced or inhibited when children attend formal schools (Cashdan et al., 2016; Davis et al., in press; Davis & Cashdan, 2019). The variation in school curricula, quality, and schooling cultures between and within countries reveals the rich and diverse ways that modern schooling shapes our cognitive and motivational capacities with consequent effects on several cognitive abilities (Ripley, 2013).

Building on existing work (Flynn, 2007), we've argued that in many modern societies, a variety of cultural factors have cultivated a set of specialized cognitive skills that foster success in the meritocratic institutions of these societies (Flynn, 2012; Furnham & Cheng, 2013; Muthukrishna & Henrich, 2016; Nisbett et al., 2012). These cognitive skills, which have improved dramatically over the last century in the wealthiest societies, relate primarily to analytic thinking, including abstract problem-solving, working memory and pattern recognition. Indeed, some of the most striking increases have occurred in the supposedly "culture free" aspects of cognition, such as those measured by Raven's Matrices and the three analytic subtests of the Weschler IQ battery. In the particular societies commonly studied by psychologists, measures of these cognitive abilities tend to cluster, giving researchers the impression that they form some innate dimension of "intelligence." Of course, what a particular society labels "intelligence" may represent merely the suite of cognitive skills that promote success or prestige within that society during a particular era. Consistent with this, Uchiyama and colleagues (2022) argue that the genetic heritability of any traits favored by cultural evolution in a particular ecological or institutional environment, such as the cognitive suite labeled "IQ", will tend to increase over time—cultural evolution can operate to decrease the total phenotypic variance or increase a trait's genetic variance (Zeng & Henrich, 2022).

Consistent with this view, studies of schooled and unschooled populations show that the "natural" maturational patterning of IQ arises from the interaction between maturation and schooling (Davis, 2014). Indeed, meta-analyses of causal and quasi-experimental studies suggest that "Education appears to be the most consistent, robust, and durable method yet to be identified for raising intelligence." (Ritchie & Tucker-Drob, 2018). Since universal schooling is relatively recent, and didn't exist at all over most of human evolutionary history, much of the work on "intelligence" and IQ is really a form of cultural psychology.

For our current purposes, the point is that cumulative cultural evolution has fostered a suite of cognitive skills that made people 'smarter' in the sense of being better able to meet the cognitive challenges posed by their societies and environments. Consistent with this, Greenfield (1998) points out that early in the 20th century, IQ scores in rural American towns increased dramatically just as these towns were wired into the United States' collective brain through investment in schools, roads and railroads. The same process can be observed a half century later in Guatemala and a full century later among the Tsimane in the Bolivian Amazon. Growing Collective Brains made people 'smarter' in the culturally-situated sense captured by IQ tests.

Finally, cumulative cultural evolution has shaped a variety of cultural ontologies and epistemologies. The ontologies and epistemologies that we acquire as a consequence of growing up in a particular place

influence the kinds of explanations we consider, the types of evidence we value, and our assessments of what constitutes a good argument. We culturally inherit fundamental ontologies about how the world works. For example, if you are feeling sick, which of the following do you consider as a potential cause: (1) germs, (2) envy from others, (3) sorcery or (4) genes? Even if you are not sure, the candidate cause can impact your actions and thus the kinds of innovations you might devise. In many, if not most, populations over human history, witchcraft was considered a major cause of illness (Singh, 2021). In many societies, both today and historically (Gershman, 2022), when a person dies unexpectedly, inquests and trials are conducted, evidence is presented, arguments are made, verdicts are rendered, and executions of witches are carried out. In England, for example, witchcraft trials didn't completely disappear until 1944, when Helen Duncan was convicted under the Witchcraft Act of 1735 for revealing military secrets that she'd (purportedly) obtained during seances. Without reviewing the evidence, which convinced a jury, those of us with a WEIRD ontology feel confident that she was wrongly convicted. But have you reviewed the evidence against witchcraft? Probably not. Despite the intuitive attractiveness of witchcraft-based explanations, your skepticism arises not from your evaluation of evidence, but from the collective brain operating through cumulative cultural evolution to gradually filter out ineffective ontologies and epistemologies. Your skepticism of witchcraft-based explanations was bequeathed to you by your cultural ancestors.

Similarly, dreams have been considered a valuable form of evidence across many populations including philosophically-sophisticated societies like ancient Greece and China (Hong, 2021). Among both emperors and peasants, dream evidence has been used to make life and death decisions about battles, illness, disasters and pregnancies. In China, specialists in dream interpretation assisted emperors for over 2000 years to make important state decisions. Official reports from the period would appear to confirm the accuracy of dreams. Today, those exposed to WEIRD ontologies generally don't use their dreams as evidence about what's likely to occur in the future (though of course, there's a fringe industry). This too isn't because they have reviewed the corpora of evidence against the epistemological value of dreams. Instead, cumulative cultural evolution gradually reduced the consideration of dreams as evidence.

Cultural evolution, operating via the collective brain, alters our ontologies and epistemologies outside of conscious awareness, gradually shaping them to aid us both individually and collectively in making better decisions and employing practices more likely to work.

The informational division of labor and collective intelligence

The Cultural Brain Hypothesis argues that the rapid expansion of our brains was driven by the ever-increasing body of adaptive information, including heuristics, know-how, practices, attentional biases and much more, made available by cultural evolution to learners with sufficient capacities for acquiring, storing and organizing this information (Henrich, 2016; Muthukrishna et al., 2018). However, based on estimates from fossils, our species cranial expansion likely stabilized roughly 200,000 years ago or more. Debates persist, but the leading hypothesis for why our brains stopped enlarging relates to the rising costs of birthing "big-headed" babies and the phylogenetic constraints imposed by the female body plan (Boyd & Silk, 2014). Even today, bigger heads result in more emergency cesarean sections and instrumental interventions (Lipschuetz et al., 2015). Nevertheless, opportunities to take advantage of the adaptive information created by cumulative cultural evolution persisted.

One way to further exploit the available cultural information would have been to subdivide communities into specialists such that cultural know-how was distributed across the minds of community members (Ben-Oren et al., 2022). Likely the first and most enduring partition of cultural know-how and skills occurred between males and females (Hooper et al., 2015; Schniter et al., 2015, 2018), with women often focusing on developing expertise in activities surrounding infant care and productive activities that could be done with young children in tow. Beyond the sexual division of labor, particular community members may have specialized in various ways (Hooper et al., 2015), including in medicinal plant use, shamanism and the manufacture of skill-intensive crafts such as making fires, arrows and skin boats. Intergroup exchange may have permitted different communities to specialize in certain skills leading to the beginnings of commerce (Henrich & Boyd, 2008; Migliano & Vinicius, 2022).

The emergence of a community-level cognitive division of labor may be sufficiently old that it has influenced our species' genetic evolution. Cognitively, such evolutionary processes may explain both why individuals readily think of themselves as part of a collective brain, with distributed knowledge, and readily assume the existence of specialists to facilitate learning and information seeking. For example, young children in WEIRD societies, and probably others, readily understand that different specialists have different information and can readily learn the role of disciplinary expertise for the purposes of knowledge seeking (Keil et al., 2008; Lutz & Keil, 2002). At the same time, in the 'community of knowledge' phenomenon, adults in both the U.S. and China fail to distinguish between what they personally know and what is understood by someone in their group (Fullerton et al., 2020; Sloman & Rabb, 2016)—they implicitly recognize they are part of a collective brain. In addition, the rise of a division of labor may have reduced the selection pressures sustaining our large, costly brains, leading to the decline in brain size observed in humans over the last 20,000 years (DeSilva et al., 2021), though the simulations of the Cultural Brain offer other explanations as well.

In the modern world, the innovative potential of countries depends on the distribution of know-how: the occupational or productive specializations of cities or countries predict the new industries or products that can be developed. Hidalgo, Hausman, and colleagues (2009; 2007; 2011), for example, they show that countries can't innovate in a certain industry or product type unless they already have particular other related product types or industries in place. These authors argue that this arises from the role of tacit knowledge—the skill or know-how necessary to accomplish specific productive activities that can't be conveyed in an instruction manual or taught in school, but only learned through apprenticeship, hands-on training and interactions with experts.

Like other animals, including ants, bees and birds (DeSilva et al., 2021; Morand-Ferron & Quinn, 2011; Pike & Laland, 2010; Sasaki et al., 2013; Seeley, 2010), humans can also take advantage of methods for aggregating information in ways that sharpen their observations, judgments and decisions. However, unlike non-humans, we have culturally evolved institutions for aggregating information that influence the ability of groups or communities to make smart decisions that depend not only on the cognitive abilities of the individuals involved but also on their diversity and norms of social interaction.

Focusing on decision-making and problem-solving in small groups or teams (Engel et al., 2015; Page et al., 2019; Riedl et al., 2021; Woolley et al., 2010, 2015), psychologists and cultural evolutionists have explored the factors that contribute to "smarter" groups. These findings confirm the basic logic of collective brain dynamics. Groups composed of more intelligent individuals, based on IQ, tend to have greater "collective intelligence," though the relationship is relatively moderate (Engel et al., 2014;

Woolley et al., 2010, 2015). Crucially, members of smarter groups are more willing and able to take each other's perspectives and listen without interrupting (Engel et al., 2014; Meslec et al., 2016) and introducing individuals with social skills for collaboration has as large an effect on team performance as individual IQs (Weidmann & Deming, 2021). In a social network, when individuals are permitted to break social ties and reform new ones, they form networks that are even better at collective judgment (Almaatouq et al., 2020). Finally, although greater cognitive diversity often increases a group's problem-solving abilities (Page et al., 2019), the cases in which diversity fails to predict improved problem-solving seem to confirm the theory—they involve cases in which measured 'diversity' was not associated with relevant informational/cognitive diversity or in which diversity resulted in less social interconnectedness, shrinking the collective brain (Schimmelpfennig et al., 2022; Sulik et al., 2022).

Epistemic Institutions

The psychological literature on collective intelligence and team innovation strongly suggests that social norms impact people's creativity and innovation by shaping organizations and influencing social interactions. These organizational traits can evolve culturally under the influence of intergroup competition: institutions that generate faster innovation or more reliable knowledge can spread in a variety of ways. The most obvious norms, institutions or policies that might influence intergroup competition flow directly from the standard findings in the collective intelligence literature: organizational norms and policies can influence (1) cognitive diversity and perspective taking through the recruiting and assignment of new members, (2) the ability of members to interact socially and vicariously (including opportunities for people to form their own networks), (3) people's openness and receptivity to novel ideas and fresh questions or claims, both of which are shaped by the cultivation of interpersonal harmony, an egalitarian ethos and the suppression of dominance-oriented status seeking (e.g., bullying, etc.).

However, beyond these elements, organizations and communities today and over historical time have possessed quite different ontological and epistemic norms. As noted, different notions of what exists (e.g., witches) or what constitutes a good argument or reliable evidence have evolved culturally. Some organizations today, such as religious communities, find arguments that invoke supernatural agents and sacred scriptural references as perfectly acceptable. That doesn't mean that they immediately believe such arguments and evidence, but such arguments do not fall out of bounds. For example, the brilliant 13th century theologian, Thomas Aquinas, unapologetically explored topics such as whether angels were corporal or incorporeal and in turn, whether several angels could be in the same place at the same time. This in turn led to later concerns about angels crowding together on the heads of pins. Obviously, scientific institutions today impose rather different ontological and epistemological standards. Echoing Aquinas, a young physicist today may explore quantum superpositions or reconciling quantum mechanics with general relativity, but they would not posit a supernatural agent to resolve the puzzle nor draw as evidence some combination of their own lucid dreams and textual evidence from Confucius, Mayan texts and the Gospel of John. She could, as Laplace and Newton did with gravitons and photons, posit a particle with particular properties. Ontologically, making up new particles is fine, just not new (or old) supernatural agents. Of course, banishing the influence of the ancient sages and sacred scripture lies at the center of scientific epistemology—no appeals to authority in making your case. Newton himself was criticized by the Cartesians for positing a "mystical" gravitational force that could instantaneously act over great distances without any physical connections or contacts. The Cartesians

happened to be right about gravity, which propagates at the speed of light not instantaneously, but their reasoning was flawed by modern scientific standards—a “mystical” instantaneous connection between entangled particles is “spooky” but ultimately acceptable. The rules by which we decide what is true and evaluate evidence are culturally acquired without direct experience nor direct evaluation of that evidence, which in any case, would be evaluated and debated based on culturally acquired standards.

The norms of an organization can institutionalize debate as we see in legislative assemblies, legal proceedings, scientific journals and conferences (Goodin, 2017). Debating formats, where each side must defend their position, may take advantage of certain psychological mechanisms that make us good at spotting the evidentiary and logical flaws in other people’s arguments but not so good at identifying the shortcoming of the arguments we devise to defend our own beliefs (Mercier, 2016; Mercier & Sperber, 2011). Of course, people can be trained to improve their arguments, but part of that training is learning how to see your arguments from the vantage of others (Castelain et al., 2016). Policies and laws surrounding free speech and academic freedom further enhance and safeguard the potential for generating reliable knowledge (Rauch, 2021). Interestingly, as with many of the practices that improve group-level innovation and creativity, individuals are bad at recognizing these norms and designing effective institutions (Mercier et al., 2015): e.g., both experts and others underestimate the power of argumentation. Moreover, the way in which these norms are shifting through new communities created by the Internet and online social networks is still evolving and yet to be worked out.

Other institutions have gradually developed other epistemic-enhancing norms, practices or laws. Some legal bodies, including both the Canadian Supreme Court and the Great Sanhedrin (the ancient assembly in Israel), had the lowest ranking members offer their views first, before they were tainted by hearing those of more senior members (Henrich, 2016). Similarly, the secret ballot spread only slowly to other modern democracies after France included it in their new constitution (1795). Today, most countries use the ‘Australian ballot,’ after it began in Tasmania in 1856. This institution surrounds the secret ballot concept with a set of practical requirements that help guarantee secrecy. Curiously, while the Australian ballot is now nearly universal, some U.S. states like West Virginia have still not adopted it.

In conclusion, a growing body of evidence supports the view that, propelled by our species’ capacities for learning from each other—our cultural capacities—humans have evolved to be ultra-social, deeply dependent on a large body of cumulative cultural knowledge for our very survival, and adapted to thinking, remembering, and reasoning as a collective (Boyd, 2017; Henrich, 2016; Muthukrishna & Henrich, 2016; Rabb et al., 2019). Human cognition can therefore only be understood when seated within its social, historical and evolutionary context (Muthukrishna et al., 2021).

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