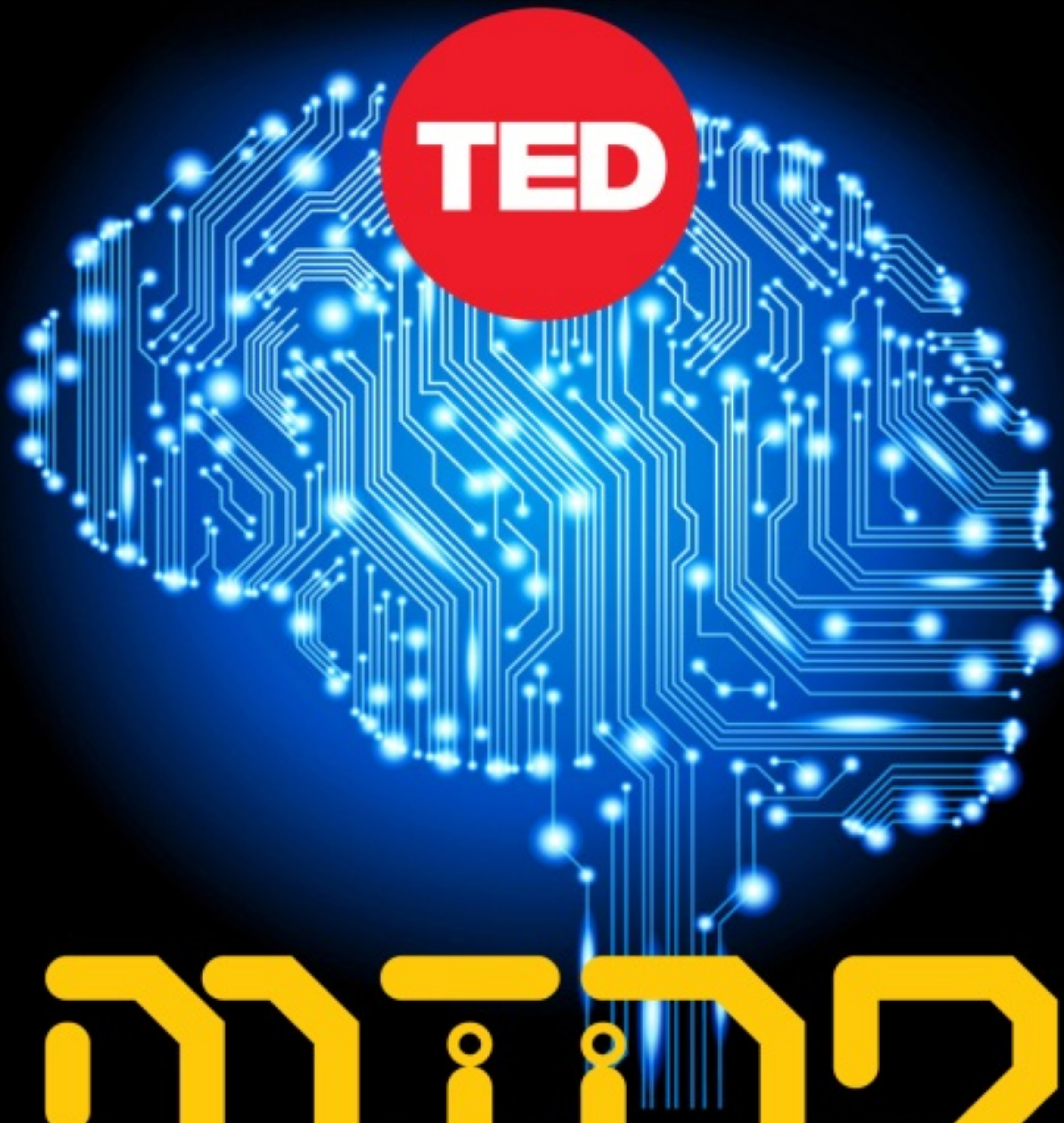
“Mind Amplifier: Can Our Digital Tools Make Us Smarter?”



MIND AMPLIFIER

Can Our Digital Tools Make Us Smarter?

HOWARD
RHEINGOLD

Mind Amplifier

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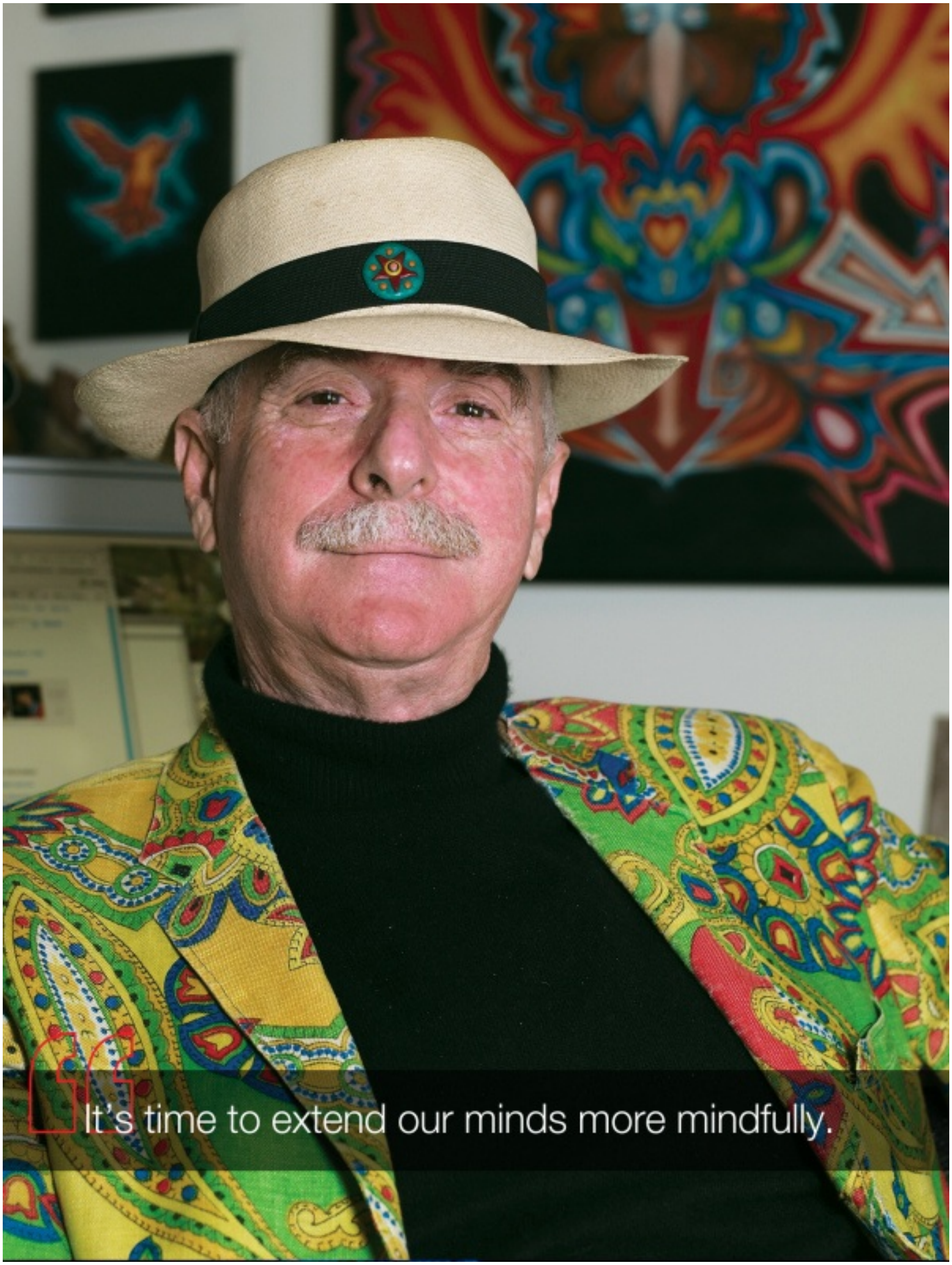

"It's time to extend our minds more mindfully.

Tools for the mind

Every day we see tremendous economic and societal enthusiasm for an enormous range of networked electronic communication gadgets that provide quick access to ideas and people everywhere. At the same time, there is an understandable apprehension that an addictive dependency on these same devices, which often provide so much, can also numb our minds and emotions, making people and culture shallow.

Instead of asking whether the Web and the various devices connected to it are making us stupid, what if we could mindfully design and use digital media to make us smarter? What if humans could build electronic tools that leverage our ability to think, communicate, and cooperate? I think we can. Humans invented social learning, speech, writing, alphabets, printing, computers, and the Internet. We should be systematically directing the evolution of intellectual augmentation.

Therefore, I want to look at this new assortment of networked devices that are so essential to our lives as the tools they really are, and examine how we may use those tools to, in turn, design more humane and effective technology. Ultimately, I will explore how we can use our machines and digital media to create an informed and socially conscious form of mind-extension. The root ideas are not my original creations. Rather, by linking together the work of media historians, cognitive psychologists, and computer visionaries, I hope to provide a framework to guide our future use of machines-to-think-with. In our species' self-interest, we need to understand the human-computer symbiosis in which we've become enmeshed.

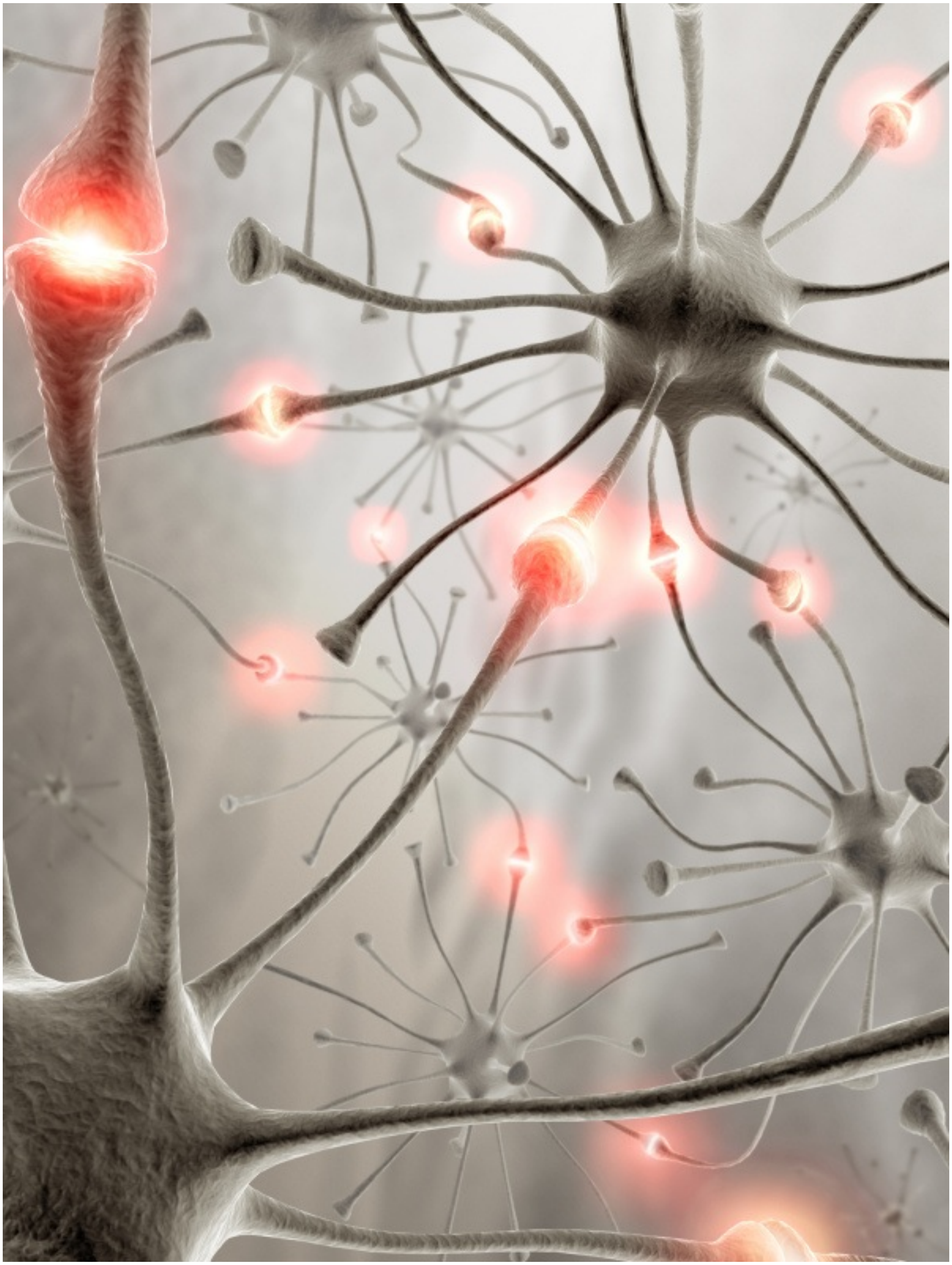
In this quest, we can certainly look to the past for guidance. Our unique ability to create thinking tools has paid off very well for *Homo sapiens* in many areas. Our primate ancestors probably became human by inventing ways to use their brains that no other species had been able to duplicate (such as foresight, language, and social learning). The democratization of alphabetic literacy enabled by printing presses, for instance, laid the foundations for democracy and science as a collective enterprise.

Conversely, we are also now aware that building powerful machines before asking how they might change us can be destructive and even dangerous. The list of those negative consequences is long and spectacular — the widespread adoption of the automobile caused equally widespread air pollution that may be changing Earth's climate; computers empower billions of people and form the infrastructure for unprecedented surveillance; nuclear weapons threaten the continued existence of human civilization.

We humans have only recently begun to learn the consequences of using our thinking tools en masse. Technologies that empower individuals can, when used by millions, exhibit emergent negative, even deadly side effects. The democratization of air travel (lower ticket costs, multiple carriers, many routes to choose from) has also enabled the rapid spread of global epidemics, for instance. Likewise, texting while driving a car is becoming a major cause of highway fatalities.

It's not just the mind-tools that matter when creating civilization shifters. Knowing how to use mind-tools is what reshapes thinking and bends history. If you know how to use mathematics and the scientific method, it becomes possible for you to build both digital computers and thermonuclear weapons. Can we piece together what we know about designing extensions of the human mind — both cognitive and technological — and use what we learn to address the life-threatening impacts of our tool use? I do not want to ignore the possibility that using new technology to solve problems arising from the use of older tools is a self-destructive loop. Neither do I want to argue for or against the probability of a “singularity” in coming decades — a hypothesized evolutionary tipping point when intelligent machines might out-think humans at such velocity that we won’t understand what our creations are up to.

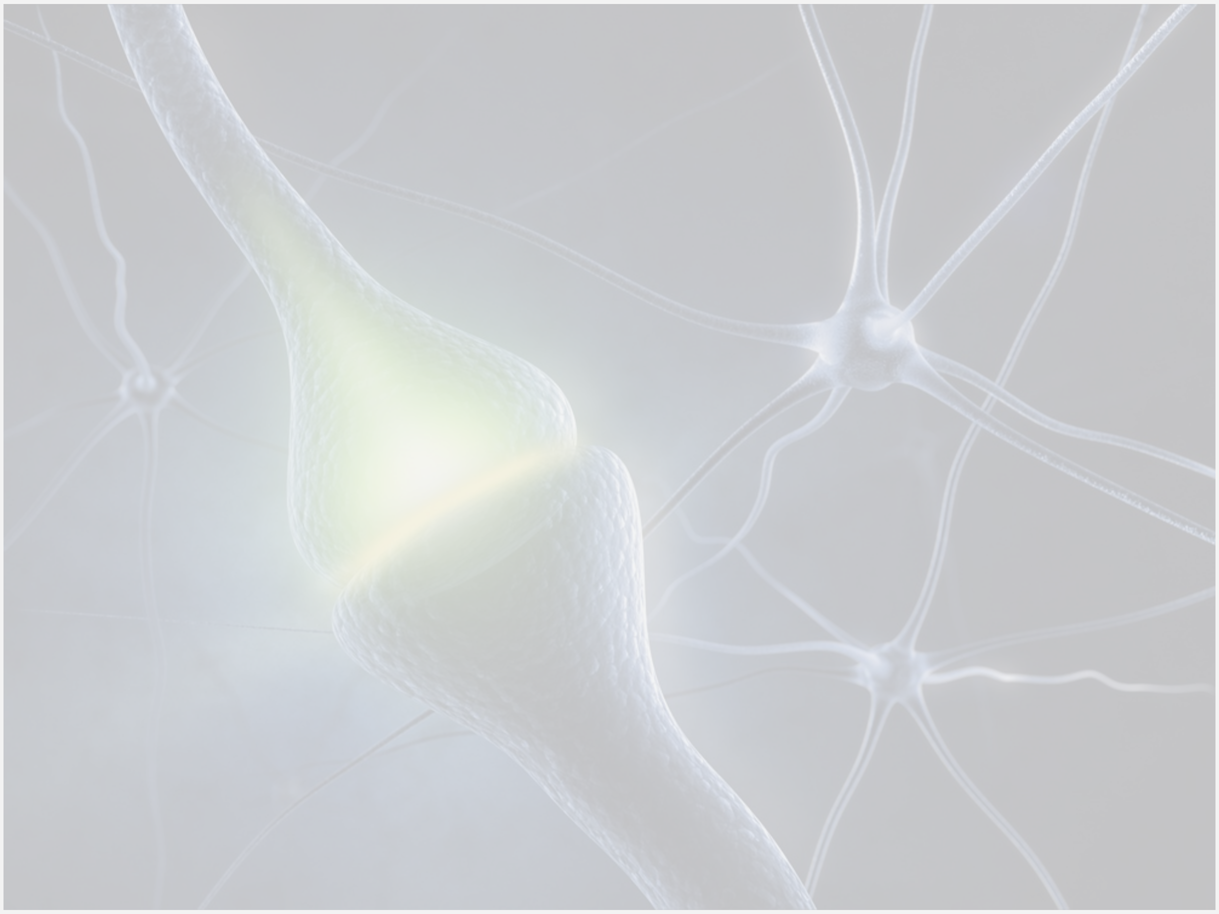
Ultimately, though, I want to consider the question that motivated some of the pioneers of personal computing: How might we build media that will enable people to think and collaborate in ways never before possible? What if using information media knowledgeably could make us smarter as individuals, as societies, as a species? This question was first posed decades ago by Vannevar Bush, J.C.R. Licklider, and Douglas Engelbart, and less successfully by Emanuel Goldberg and Paul Otlet before them.[1] [2] [3] [4] [5] Now that the technologies envisioned half a century ago have grown billions of times more powerful (and now that billions of people are using them), it’s worth reconsidering these original ideas, and how to apply new tools to their originally intended purpose. The early tech visionaries who created personal computers and online networks pursued these inventions not to create industries but to enhance problem solving. It’s time to revive the original quest that led to the development of personal digital media. It’s time to extend our minds more mindfully.



Natural-born cyborgs

The human evolutionary process sped up dramatically when language emerged. Suddenly, *Homo sapiens* wasn't just accumulating new traits over long periods of time through biological mutation and selection. When we developed language we learned to create new capabilities very rapidly, rather than waiting millions of years for evolution to configure our biological equipment. Biology provided the workable parts for thinking tools, but early humans learned to innovate by repurposing their brains and thought patterns in ways that neuroscientist Stanislas Dehaene calls "neuronal recycling."[6] Biological evolution would favor mutations that changed brains over many generations to make them more fit for their environment. But through neuronal recycling human brains learned how to use existing biological parts to perform new functions. Further, they could teach other human brains to do this as well.

Our ancestors learned to reprogram their brains to deal with the more complex social world they were creating, and the tools our forebears used for reprogramming their thinking capabilities in turn enabled them to make the social world more complex and to make even more powerful thinking tools. Thought and language created the basis for writing, which was perfected into alphabetic writing, automated through print, and amplified by digital media.



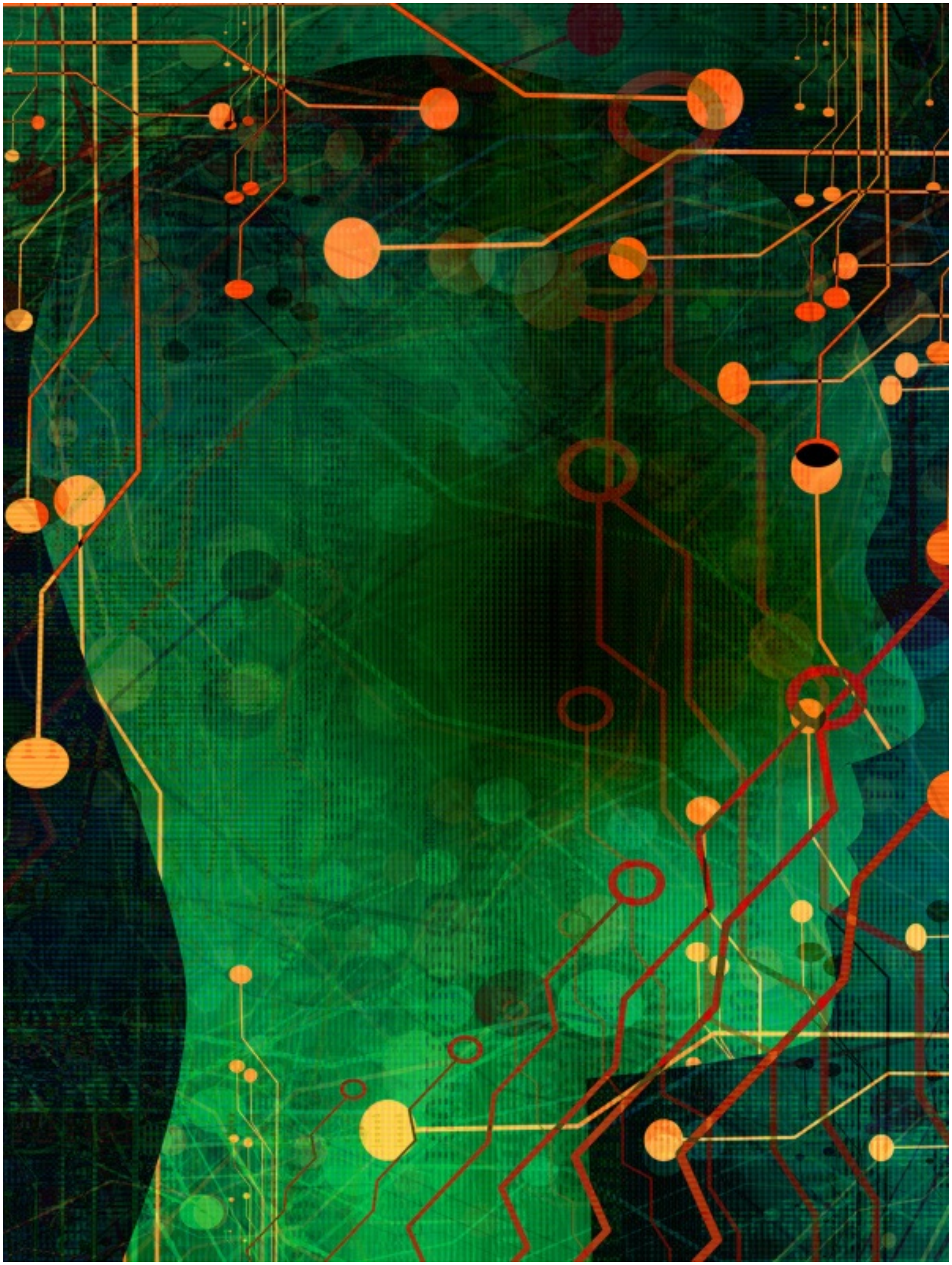
With neuroplasticity, connections between nerve cells like these can be added or removed, strengthened or weakened based on how we use them.

Image: Shutterstock

In recent decades, neuroscientists have discovered that the human brain is even more malleable than was previously believed, possessing a capacity now known as "neuroplasticity." In other words, life experience allows the brain to rewire its neural pathways and synapses. Because our brains are self-reprogrammable ("neuroplastic") and we can use language to pass our knowledge to others, mind-tools can boost our individual thinking power.

The right cognitive tools can repurpose our brains, have done so repeatedly, and are at the root of what it means to be human. Mechanical aids like writing and computation take advantage of our brains' architecture. Our brains are wired not only to learn, but to socialize in complex ways. The increasingly complex forms of social organization that our aggregate brainpower makes possible for human groups, and the talent for tool-making that our brains, eyes, and hands make possible have been co-evolving since our ancestors invented culture. And culture — everything we teach and learn from one another — was the lever by which our biological capabilities bootstrapped themselves. Culture assembled the brain's cognitive building blocks, such as abstraction, prediction, and sequencing, into new intellectual capabilities, such as reading and writing.

As Andy Clark, who is a professor of philosophy and metaphysics at the University of Edinburgh, claims, humans appear to be "natural-born cyborgs," biologically equipped to reprogram each other's thinking machinery through culture. That's where today's 2 billion Internet users come into play. Developing a mutualistic relationship with computing machinery — becoming networks of cyborgs — is taking this older process of human-tool co-evolution to a whole new level. Thinkers from cyberneticist Norbert Wiener to post-humanist Donna Haraway have noted that our cyborg powers affect our humanity, both positively and negatively.[7] [8] The question "What does it mean to be human?" is no longer an exercise for just philosophers and theologians; it is now a bioethics and engineering issue.



Augment, amplify, extend

The term “cyborg,” introduced by Manfred Clynes and Nathan Kline in 1960, originally referred to the inclusion of technology in bodies (“CYBernetic ORGanisms”). More recently, media theorists extended the term to describe people whose brains are not physically jacked in to a computer (yet) but whose nervous systems are (already) attuned — through the personal computer’s (and smartphone’s) point-and-click visual interface — to a kind of “thinking” possible only with computers.[9] Chips implanted in skulls may indeed become commonplace in the future, but the literacies needed to empower smartphone-carrying individuals already exist. Priests who inscribed language on clay tablets in ancient Sumeria were cyborgs, just as your Bluetooth earphone makes you one.

When I talk about “cyborg literacy,” I mean a set of skills and social practices that optimize the ability to use physical and cognitive technologies to augment, amplify, or extend human thinking and communication capabilities. This not only includes an ability to enhance problem solving but also to incorporate a balance of individual autonomy and collective interdependence; networks of trust; and norms of reciprocity, empathy, compassion, and conviviality that are absent from strictly engineering-oriented or purely market-based approaches.

While my initial enthusiasm for digital media as powerful tools for my professional pursuits of writing and teaching has not waned, I cannot help observing the ways in which the world is NOT a better place for the past 30 years of cybernetic innovation. The pitfalls and the hidden prices of technology are more visible, and industries that sprouted from the dreams of engineer-utopians can, in hindsight, lack an essential ethical dimension. Facebook has redefined privacy (and not always for the better), pilotless drones with face-recognition technology target individuals, students play online games during lectures, and exploited labor and conflict minerals are part of the smartphone ecosystem.

It would benefit all of us to learn how to use our ubiquitous gadgets for our own good. To that end, a pattern of thought and theory and possible practical design advice is emerging around mind-extension. The ideas worth spreading include arguments about where human fascination with making machines came from, and where we, and our machines, ought to go next:

- *The human mind is a self-evolving organ. The invention of speech, writing, mathematics, logic, algorithms, computation, and human-computer interfaces has been an ongoing process of cyborg co-evolution for hundreds of thousands of years.*
- *Our species' unique capability to learn and teach brought Darwinian dynamics to cultural evolution — survival-enhancing tools and ideas spread quickly, upgrading the capabilities of all humans within communication range.*
- *Literacies made possible by these thought-tools have shifted the course of civilizations, necessitating the creation of new intellectual tools to deal with the complexities that older tools enabled.*
- *The automation of external symbol-manipulation by computational media and the interconnection of minds and information afforded by many-to-many networks has made it possible for people to more deliberately design powerful cognitive tools. The Internet made the Web possible, and the Web made Wikipedia possible. We're beginning to see how the process of using old tools to create new tools works. This means we can influence or exert control over the process of evolution of the extended mind rather than simply coping with it.*

Co-evolving with our tools

Those who hope to influence the future of the extended mind should consider its origins. Not only can humans reprogram our mental toolkit in ways no other creature is known to do — we call it "social learning" — the human brain's self-reprogramming capabilities seem to have arisen from, and remain coupled to, a co-evolutionary upward spiral. The benefits of this are many, including evolved biological capabilities such as bipedalism, opposable thumbs, big forebrains, sociality, and inventiveness; artificially created tools such as chipped arrowheads, clay tablets, and microprocessors; and symbolic communication media such as speech, the alphabet, and the point-and-click human-computer interface. Each factor drives each other factor to grow more powerful.

One of the first people I met when I started exploring the budding online culture in the late 1980s was a scientist named William Calvin. His research combined paleontology, evolutionary biology, and neuroscience. He has since written several books presenting evidence that the large brains and unique capacities of *Homo sapiens* were shaped by sudden climate change tens of thousands and hundreds of thousands of years ago.[10] When I met him, Calvin was in the process of elaborating his theories. I had the opportunity to engage him online and directly at the face-to-face parties held by our early virtual community (the Whole Earth 'Lectronic Link — the WELL — for which I popularized the term "virtual community").

Calvin's first book, which I read a couple of years before I met him, was evocatively named *The Throwing Madonna*, because it presented the argument that brain mechanisms for speech are closely connected with brain mechanisms used for ballistic calculations — like throwing a rock at a moving rabbit.[11] In order to hit a moving target, different neural computation networks are required to make predictions and sequence actions. These brain mechanisms, Calvin hypothesized, were later adapted to form sentences in the brain and coordinate the muscular actions required to speak them — estimating where a running rabbit is likely to be when your stone reaches that location turns out also to be useful for modeling the future, planning actions, and putting words together into meaningful sequences. Think about the way some invisible mind mechanism seems to fetch the right words to finish your sentences, even if you weren't sure where they were going when the sentences started.

Language encourages generative thinking — not just learning and remembering, but inventing. Even the least creative person invents new sentences every day. Invention and learning by searching for what might turn out to be useful, testing it, and adopting the experiments that work is another uniquely human capability that might have grown out of the need for rapid ballistic estimates.

The way living organisms can adopt biological organs for new purposes forms the basis for what Calvin and others claim to be our species' talent for "exaptation." This gradual repurposing of previously evolved organs to create new organs, requiring random mutations and millions of years, explains how small bones in the jaws of ancient reptiles turned into auditory organs. Human exaptation is uniquely powerful because of our ability to repurpose in real time the way we use our innate information-processing hardware — and to teach others how to do it. We don't have to wait for mutations to enable us to read and write; we can use parts of our brains to quickly read and understand tracks in the mud and to throw rocks more accurately. Likewise, we can recognize groups of visual symbols as words and then sequence those words into sentences.

"Co-evolution" is another term that characterizes the way humans, tools, and culture bootstrap each other. In biology, species co-evolve when they trigger changes in each other over time that increase their fitness to the environment. Faster and faster predators co-evolve with increasingly smarter prey. Oxygen-producing organisms co-evolve with oxygen-consuming organisms. That same form of co-evolution occurs with humans and our tools, both mental and physical.

Just as other predators evolved claws, wings, or venom, our predecessors developed abilities to make complex tools, forecast the future, learn by watching others of our species, and coordinate action among ourselves by communicating with linguistic symbols. Once the biological machinery for our self-reprogramming brains evolved, the collection of practices we now call "culture" shifted human evolution into hyperdrive.

In the beginning, the ability to walk on two feet freed the hands of our primate division to grasp and use external objects as extensions of their muscles. Many of the proto-traits that led to language were about the use of our brains as well as about the capabilities of our vocal cords, tongues, and lips.

Our mastery of attention, for example, is foremost among the traits that enabled humans to invent and evolve culture. We share with other primates the existence of "mirror neurons" that fire not only when we perform a task, but also when we see others performing a task — the basis for internal models of others' behavior.[12] Uniquely among primates, our species will look where another member of our species points, and baby humans quickly learn to pay attention to what their mothers focus on.[13] We are the only primates with large white areas in our eyes, enabling other humans to discern the attentional focus of others.[14] Mindfulness and metacognition — thinking more effectively by becoming more aware of our thinking — are both useful consequences of our attentional capabilities and clues to designing better mind-tools.

Inventing literacy

Learning from others requires not just the capacity to pay attention and to model the intentions and beliefs of others, but a set of social skills as well. Anthropologist Robin Dunbar and others have argued that the need for complex neural computations such as facial recognition and memory of past behavior — required by the need to keep track of reputation, reciprocity, and cooperation — drove the growth and exaptation of the evolutionarily youngest part of the human brain, the neocortex. “The principal function of language was (and is!) to enable the exchange of social information (‘gossip’) in order to facilitate bonding in larger, more dispersed social groups,” Dunbar wrote in a famous paper about co-evolution of neocortical size, group size, and language in humans.[15]

As our ancestors learned to capture fire and to alter the environment to their benefit, make more complicated tools, divide labor, cook, share food, and organize collective defense against predators, they were able to create more socially complex ways of life that enhanced their chances of surviving and reproducing. Extreme, sudden changes in climate killed off those proto-human groups that were not able to respond to changing conditions. The emergence of new levels of social complexity around 100,000 years ago, media ecologist and physicist Robert Logan argues, stimulated thought and language.[16]

I traveled to Toronto to talk with Logan about extended minds, their origins, and their future. Logan reasserted the claims in his books that stone tool-making interacted with control of fire, coordinated hunting, and mimetic communication using gestures and primitive vocalizations, to create the conditions for the emergence of language when severe environmental changes necessitated radical innovation.

“When we gained words as containers for ideas, humans started to think in concepts instead of percepts,” Logan reminded me.

The road to microchips started when humans began growing food instead of hunting for it. About 10,000 years ago, agriculture arose, nomads started to live in stationary settlements, big cities grew, kings became emperors, large-scale irrigation projects required hierarchical social organizations, and the conditions ripened for another autocatalytic bootstrapping of our intellectual capabilities. About halfway between then and now, around 5,000 years ago, writing emerged as a cultural exaptation. Its history is now more clearly understood: Clay figurines used by Sumerians to account for economic transactions evolved into *representations* of figurines, impressed on clay tablets, after which the transaction system was further appropriated to encode and transport knowledge of all kinds across time and space.

■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A clay tablet dated to 2350 B.C.E. bears an accounting of monthly barley rations given to adults and children. The tablet comes from Ngirsu, an ancient city of Sumer located in modern-day Iraq, and is displayed at the British Museum in London.

Image: Public domain

The invention of writing bootstrapped human knowledge-generating capabilities in stages, beginning with economic transactions, evolving into a general-purpose tool for encoding and transmitting knowledge, and later being reinvented in a highly abstracted and far more learnable form, alphabetic literacy.

The discovery of hundreds of identical small, clay objects in Sumerian excavations posed a mystery to archaeologists for decades until Denise Schmandt-Besserat traveled to museums in the Near East, North Africa, Europe, and North America and pieced together the physical evidence of how a writing system emerged.[17] She identified the objects as tokens representing transactions — "calculi." Although the use of tokens has been traced back to 8000 B.C.E., around 3300 B.C.E. these tiny symbolic representations of sheep or bushels of wheat began to be baked into clay envelopes as a kind of tangible contract (for example, "I contributed four bushels of wheat to the royal granary"). Impressions of the tokens were made on the outside of the envelope, so it wouldn't be necessary to break open the baked clay to count the number of tokens inside. Eventually, the accountants for Sumerian emperors — the first literate class — abandoned the use of tokens inside baked containers and used tokens to stamp the outside of the containers. Later, they started inscribing abstractions of the stamped figurines by using a reed to incise lines on wet clay. Inventions build on previous inventions; abstractions encapsulate previous abstractions. New social classes (scribes who worked for priests who worked for emperors) were trained in the arts of reading and writing.

The use of clay tablets to encode non-transactional information was a milestone in encoding knowledge. It was also an extension of mental capacities through the use of external objects to convey symbolic information. With writing comes reading, a forced reprogramming of young brains to recognize, extract, and construct meaning from a small set of visual symbols. And with reading came the first schools, where we reprogram the young of our species by teaching them alphabets and grammars. Reading specialist Maryanne Wolf noted that humans were able to make use of visual tokens by connecting visual regions of the brain to nearby neural networks responsible for higher-level activities like deciphering meanings:

> *Symbolization, therefore, even for the tiny token, exploits and expands two of the most important features of the human brain — our capacity for specialization and our capacity for making new connections among association areas.*[18]

Consider just a few of the things our brains have to do when we read. We have to recognize a visual pattern, decode the meaning assigned to perceptible symbols, arrange and deconstruct sequences of letters and words, and plan sentences. Each of these tasks is accomplished by different brain regions and neural networks. As Calvin suggested, perhaps rapid sequencing grew from ballistic calculation functions, or perhaps, as Dehaene conjectured, “It is possible that reading animal tracks is the cortical precursor for reading. If evolution has yielded bodily specializations as refined as the eagle’s eye or the leopard’s leap, it no doubt can modify the predator’s visual brain. The intense selective pressure imposed by millions of years of interaction between predators and prey may have led to a cortical specialization for reading animal tracks."[19]

Speaking and reading use the brain. Learning how to speak and read also *change* the brain of the learner. Because "nerves that fire together, wire together" (aka Hebb's Postulate), the rote evocation of association between sounds, meanings, and alphabetic symbols actually grooves certain neural networks, certain cognitive maneuvers, into students' brains.[20] As Wolf put it:

> *It would seem more than likely that the reading brain exploited older neuronal pathways originally designed not only for vision but for connecting vision to conceptual and linguistic functions: for example, connecting the quick recognition of a shape with a rapid inference that this footprint can signal danger; connecting a recognized tool, predator, or enemy with the retrieval of a word.*[21]

The humans who invented literacy, Wolf argued, combined our species' capacity to make new connections between existing brain structures, an ability to invoke precisely specialized neural networks within our brains to recognize information patterns, and a talent to train these brain mechanisms to work together automatically, without conscious direction, once they are learned. When a young human is trained to read — and ancient Sumerian artifacts depict rows of students listening to their teacher — these disparate brain functions are forced into coordination.

Stanislas Dehaene, in *Reading and the Brain*, reminds us of Plato's warning (in the guise of a dialogue between a god-king, Thamus, and a god, Theuth, inventor of letters) that writing and reading with the newly developed Greek alphabet will cause memories to wither, "having the show of wisdom without the reality."[22] As a scientist, Dehaene brings the evidence of his research to back up this assertion, in response to Plato:

> *Learning to read clearly improves verbal memory. Illiterates can remember the gist of stories and poems, but their verbal working memory — the temporary buffer that stores instructions, recipes, names, or phone numbers over short periods of time — is vastly inferior to ours. ... When children learn to read, they return from school "literally changed." Their brains will never be the same again.*[23]

The role of culture

Reading is not just a vehicle for conveying useful knowledge and a mind-altering thought-tool. Another important function of language and writing is coordinating social activity, whether that's the Code of Hammurabi or the U.S. Constitution. We expect reading to amplify cooperation, which in turn catalyzes new institutions and forms of sociality. Some anthropologists identify cooperation as the most powerful social meta-tool that humans have invented so far. British scientist Matt Ridley put it this way:

> *When we moved away from self-sufficiency and began to work together, combining our knowledge, the consequence was far-reaching: We created things we could not and do not understand, from cordless mice to urban metropolises. Cooperation turned us into specialists: I'll do this job, you do that one. Specialization gave us incentives to innovate. Innovation led to yet more specialization and more ways of combining different specialized skills. Human intelligence became collective and cumulative to an extent that no other species can rival.*[24]

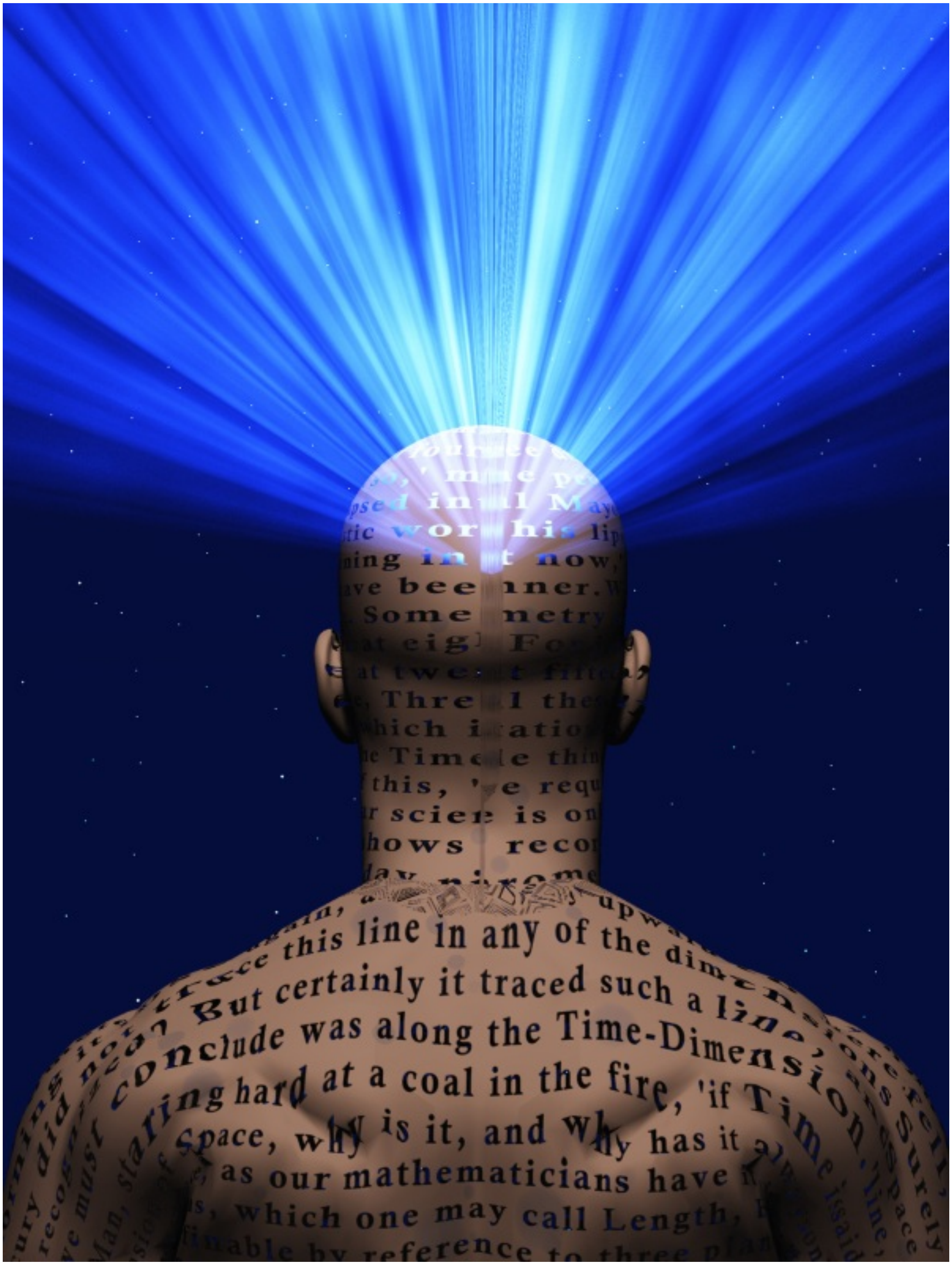
According to a school of evolutionary anthropologists, innate human propensities for cooperation with strangers, shaped during the Pleistocene in response to rapidly changing environments, could have provided highly adaptive social instincts that more recently co-evolved with cultural institutions. Although the biological capacity for primate sociality evolved genetically, these authors propose that channeling of tribal instincts via symbol systems has involved a cultural transmission and selection of traits that continues the evolution of cooperative human capacities at a cultural rather than genetic level. In *Cultural Evolution of Human Cooperation: Summaries and Findings*, evolutionary anthropologists Robert Boyd, Joseph Henrich, and Peter Richerson argue that human cooperation has enormously beneficial social technology, which evolved culturally as behavioral and emotional traits that spread and persisted within groups. This is similar to how genetically endowed traits evolve over long time spans.[25] (Richard Dawkins and Susan Blackmore, who have proposed and elaborated theories of "memes" — units of meaning that propagate via human minds and networks — have converged on similar ideas from an evolutionary perspective.)[26] [27]

Culture, in the view of Boyd, Henrich, and Richerson (as well as Dawkins and Blackmore), is an inheritance system with Darwinian dynamics. It uses symbols, imitation, norms, and learning to transmit behaviors from individual to individual, group to group, and generation to generation the way genes use DNA to transmit traits hereditarily. Small variations in cultural inventions, like small mutations in genetic lineages, favor the variants that are better suited to the environment, including the cognitive and social environments. Although the methods of manufacturing Acheulean hand-axes by our ancestor *Homo erectus* did not vary for around a million years, the complexity and pace of change in stone tools accelerated around the time paleontologists believe language developed among *Homo sapiens*.[28] One of the meta-inventions that began to co-evolve strongly with language was collective action — the ability to plan and coordinate increasingly sophisticated and larger-scale ways for humans to work together for mutual benefit.

By educating entire populations in the norms of cooperation and mind-tools of innovation, creating conditions for culturally expert people to concentrate in growing numbers in cities, connecting them through media, and giving them the means to tell all others about whatever useful trick or tool each has found or invented, culture has driven its own transformation to increasing levels of power and complexity. And this brings us to the present predicament of a global civilization, highly interconnected, partially educated, and threatened by the unintended side effects of our own powerful inventions.

From nuclear meltdowns to climate change, toxic waste dumps, carcinogenic radiation and species die-offs, today's challenges present unprecedented difficulties for the human capacity to invent new ways to solve life's problems in the face of radical environmental change. One of the strongest tools we have on our side is the capacity to change how we think.

For better or worse, billions of people have become accustomed to regular use of tools that change how we think. Wouldn't we be better off if we knew a little more about that process? What might we learn by looking at the way previous mind-tools, especially the alphabet, altered the way people thought 2,500 years ago?


this line in any of the
But certainly it traced such a
conclude was along the Time-Dimension
hard at a coal in the fire, 'if
Space, why is it, and why has it
as our mathematicians have
which one may call Length,

The alphabet effect

"Do you still argue that the alphabet created the unique conditions for the flowering of science, logic, and mathematics in ancient Greece?" I asked Logan, when we had dinner in September 2010.

"Absolutely," he replied with enthusiasm.

Logan is a physicist by training, but he has followed the discipline of historical media analysis pioneered by Harold Innis, Walter Ong, and Logan's mentor and co-author, Marshall McLuhan. Logan then quoted McLuhan's book *The Gutenberg Galaxy:* "By the meaningless sign linked to the meaningless sound we have built the shape and meaning of Western man."[29] The Greek alphabet built on its Semitic and Phoenician predecessors by adding a few vowels to a couple dozen consonants. "If you have meaningful signs like ideograms that resemble something visually," Logan told me, "you'll need thousands of signs."

Logan wove together the work of several predecessors, then built upon that foundation. Innis, an older colleague of McLuhan's at the University of Toronto, had set forth the basic idea upon which Logan and McLuhan elaborated — that the alphabet was a mind-tool that extended parts of the brain. Innis wrote:

> *The art of writing provided men with a transpersonal memory. Men are given an artificially extended and verifiable memory of events and of objects not present to sight or recollection. Individuals applied their minds to symbols rather than things and went beyond the world of concrete experience into the world of conceptual relations created within an enlarged time-and-space universe. The time world was extended beyond the range of remembered things and the space world*

beyond the range of known places. Writing enormously enhanced a capacity for abstract thinking which had been evident in the growth of language in the oral tradition.[30]

Logan and McLuhan took the idea of the alphabet as a thought-shaper much further than Innis did, arguing that quite apart from the content of alphabetic communication, the process of (specifically alphabetic) reading and writing trained the human brain and aimed (specifically Western) cultures toward abstract thinking, logical analysis, and proto-scientific classification systems.

Logan says, "By forcing us to both analyze and unpack abstractions when we decode letters and phonemes, by training our thinking in sequential ordering, by providing a classification schema through alphabetization, the alphabet makes it far easier to think in certain ways."

The invention of movable type 2,000 years later turned the alphabet into a cultural power tool. Although around 30,000 handwritten books existed in Europe in Gutenberg's lifetime, around 30 million existed 50 years after the invention of the printing press.[31] As explicated by Elizabeth Eisenstein in *The Printing Press as an Agent of Change*, the vast expansion of reading-powered thinkers from a tiny elite, handpicked and supported by the Church, into entire populations during the Protestant Reformation, made new collective cultural forms possible.[32] Instead of waiting for an Aristotle or a Newton to come along, science became a collective enterprise, with thousands of literate observers adding data and building upon each other's work. The revolutions that replaced monarchs with constitutions were led by literates who coordinated the overthrow of old orders and then wrote the charters for new ones.

Computerized thinking tools

Inside a thatched hut in the Philippines in August 1945, a young U.S. Navy radar operator named Douglas Engelbart picked up *The Atlantic Monthly* and read with interest an article written by Vannevar Bush. Bush had been the civilian in charge of the U.S. scientific war effort, including both the first electronic digital computer and the first nuclear weapons. The article, “As We May Think,” confronted the challenges that the success of science had posed: “The summation of human experience is being expanded at a prodigious rate, and the means we use for threading through the consequent maze to the momentarily important item is the same as was used in the days of square-rigged ships.”[33] Bush proposed that we needed new kinds of information machines, perhaps using microfilm. Although his long-term vision proved to be accurate, Bush’s near-term focus on opto-mechanical technologies was ironic, if only because the ENIAC (the first electronic digital computer) was one of the projects under his overall supervision.

After the war, Engelbart found work as an electrical engineer. While he was commuting to work in the Santa Clara Valley — a sprawling expanse of fruit orchards at that time, now Silicon Valley — he thought about what to do with the rest of his life. He remembered Bush’s article and wondered whether the ability to paint pictures in light on radar screens or television sets could be coupled somehow with computers’ information-processing capabilities. When Engelbart conceived this idea, television was a new medium, and there were only a few mainframe computers in the entire world, each with total system memory less than that devoted to a single icon on one of today’s smartphones. If computers could be configured to translate complex concepts into visual form, Engelbart conjectured, then the humans who used these radically redesigned computers might be able to solve problems together in ways never before possible.

This was a bold and, to many, downright weird notion when Engelbart conceived it. He was told that he could study computer science if he kept quiet about his science-fiction ideas about computerized thinking tools.

In the 1950s and early 1960s, computers were used for scientific calculations, air defense systems, big business data processing, and the census. Computers were expensive and huge; they required air-conditioned rooms; and problem-solvers could only approach the machine through a priesthood of programmers and computer operators. Commands to the computer were translated into holes punched into cardboard, and results were returned as printouts on long stacks of fanfold paper.

While Engelbart was watching radar screens in the Pacific, a scientist from Harvard was working at a military laboratory outside Boston. J.C.R. Licklider had been a psycho-acoustician before World War II. Returned to his scientific investigations after the war, Licklider grew frustrated with the long hours that he, as a scientist, spent "getting into position to think."[34] Like Engelbart, Licklider imagined that computers might evolve into machines to help scientists — if only there were a better way to link scientists with computers than punch cards and printouts.

Licklider had been influenced by the development of electronic visual dashboards for air-defense command and control that he had seen in his war research, and in 1960 he published "Man-Computer Symbiosis," in which he proclaimed a vision: "The hope is that, in not too many years, human brains and computing machines will be coupled very tightly, and that the resulting partnership will think as no human brain has ever thought and process data in a way not approached by the information-handling machines we know today."[35]

After the Russian launch of Sputnik in October 1957 frightened the

U.S. Defense Department into creating the Advanced Research Projects Agency, Licklider was hired to take over the not-very-large Information Processing Techniques Office. He began funding computer scientists and programmers around the United States to invent a kind of "interactive computing" that would enable humans to engage directly with computers instead of through the mediation of punch cards and computer operators.

One of the people Licklider funded was Ivan Sutherland, who created interactive computer graphics.[36] Another was Engelbart, whose Augmentation Research Center at Stanford Research Institute built upon Sutherland's work, inventing the mouse, hypertext, outlining, and word-processing, and becoming the first Network Information Center for the ARPANET, the ancestor of today's Internet.[37]

Make no mistake about the Faustian origins of computing machinery. Just as the proto-human brain's capability to make fast ballistic calculations may have been exapted by linguistic word-marshaling capabilities, the machines that Engelbart wanted to use to help humans solve problems were originally created to perform ballistic calculations.

Neither Licklider's interactive computing nor Engelbart's intellect augmentation and electronic digital computers would have been possible without military funding, for both the Cold War and the battlefield. Computer graphics grew out of air defense systems; the fundamentals of modern computer programming were devised to run calculations for the first thermonuclear bomb.[38] The Manhattan Project during World War II instilled a healthy respect for scientific visionaries in the U.S. military-industrial complex, which supported (and some would say exploited) a few of the best and most imaginative thinkers. Mathematician John von Neumann, a key member of the Manhattan Project, had been an enthusiastic weaponeer. But the explicitly stated intentions of Bush, Licklider and Engelbart — to improve the capacity of humans to think, co-create knowledge, and solve problems together — were larger and more broadly human than (just) lethal weaponry. Personal computing is a cultural exaptation of technologies dreamed of by visionaries and funded by warriors since the 1940s, and mass-marketed by entrepreneurs since the 1970s. Personal computing power not even the U.S. Defense Department could afford a few decades ago is now in billions of hands.

Bootstrapping

When he started to focus on his image of collaborative teams employing screens and computers to think with, Engelbart sketched out a system of "humans, using language, artifacts, methodology, and training" to invent even more capable augmentation tools, a process he called "bootstrapping." Although his work preceded by decades that of today's extended-mind theorists, Engelbart sought a system situated partially in machinery, partially in thought processes, that used both realms in a coordinated manner. He published his argument in a 1962 paper that should be required reading for all of today's designers of mind-extending tools, "Augmenting Human Intellect."[39] In this this visionary document he described a step as momentous as the repurposing of clay writing from keeping track of economic transactions to recording general knowledge — the transformation of automated symbol-processing into a machine to think with:

> *By "augmenting human intellect" we mean increasing the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to problems. Increased capability in this respect is taken to mean a mixture of the following: more-rapid comprehension, better comprehension, the possibility of gaining a useful degree of comprehension in a situation that previously was too complex, speedier solutions, better solutions, and the possibility of finding solutions to problems that before seemed insoluble. And by "complex situations" we include the professional problems of diplomats, executives, social scientists, life scientists, physical scientists,*

attorneys, designers — whether the problem situation exists for 20 minutes or 20 years. We do not speak of isolated clever tricks that help in particular situations. We refer to a way of life in an integrated domain where hunches, cut-and-try, intangibles, and the human "feel for a situation" usefully coexist with powerful concepts, streamlined terminology and notation, sophisticated methods, and high-powered electronic aids.[40]

Engelbart took up Bush's quest for a tool to handle the growing complexities of scientific knowledge:

Man's population and gross product are increasing at a considerable rate, but the complexity of his problems grows still faster, and the urgency with which solutions must be found becomes steadily greater in response to the increased rate of activity and the increasingly global nature of that activity.[41]

And he explicitly described the foundations of the device he sought to build: "We see the quickest gains emerging from (1) giving the human the minute-by-minute services of a digital computer equipped with computer-driven cathode-ray-tube display, and (2) developing the new methods of thinking and working that allow the human to capitalize upon the computer's help."

From the beginning, Engelbart recognized that internal and external tools must be coupled in an integrated system that includes physical artifacts as well as specific language, methods, and training that interconnect mental and physical technologies.

Knowledge of how to use augmentation tools was not relegated to a support function. Rather, it was integral to Engelbart's original intention:

> *Pervading all of the augmentation means is a particular structure or organization. While an untrained aborigine cannot drive a car through traffic, because he cannot leap the gap between his cultural background and the kind of world that contains cars and traffic, it is possible to move step by step through an organized training program that will enable him to drive effectively and safely. In other words, the human mind neither learns nor acts by large leaps, but by steps organized or structured so that each one depends upon previous steps.*[42]

Although he wasn't an expert on psychology or learning, Engelbart understood the power of mind-tools, especially how they build upon and leverage each other:

> *Each individual develops a certain repertoire of process capabilities from which he selects and adapts those that will compose the processes that he executes. This repertoire is like a tool kit, and just as the mechanic must know what his tools can do and how to use them, so the intellectual worker must know the capabilities of his tools and have good methods, strategies, and rules of thumb for making use of them.*[43]

The word "metacognition" was not used at the time Engelbart likened the mental repertoire of learned process capabilities to a tool kit. He didn't discuss the fit between the human mind's and the digital computer's hierarchies of abstractions. Even so, that is what he describes when he uses the example of a screen-based word-editing tool that could be used to point and select passages with a mouse and move them around on a screen, instead of retyping a piece of paper. Wouldn't boosting the capabilities at the lower end of the process hierarchy — the ability to revise drafts — make more opportunity possible at the higher end, where ideas expressed in those drafts could be imagined and tested more extensively? When you have to scribble and retype the page over and over again, your capacity for imagining alternative wording is limited.

As a professional writer, I had been using a manual and then an electric typewriter for more than 10 years when I tracked down the Alto computer at Xerox Palo Alto Research Center and talked my way into a contractor job that gave me access to this early mind-amplifying writing machine. Around the time I made the transition from typewriters to word processors, I first read Engelbart's "Augmenting Human Intellect." Engelbart wrote, "The important thing to appreciate here is that a direct new innovation in one particular capability can have far-reaching effects throughout the rest of your capability hierarchy."

The evolution of collaborative multimedia document-creation, hyperlinked knowledge networks, and mobile computation and communication media has led to a flowering of aesthetic, intellectual, and financial innovations. More and more empirical study is now devoted to the ways that our media practices reshape our brains. Looking back at what Bush, Licklider, and Engelbart envisioned, is it possible to envision a deeper interdisciplinary study and application of mind-extending technology? Rich research literatures have grown up around computer-supported cooperative work, various aspects of computer-human interface, knowledge management, and collaborative media. How could extended-mind theory be useful as a framework for designing the future of augmentation?

Putting together what is known now about humans, computers, and media, where would we want mind-extension to go next, if we had any say in it?

Metacognition

"Metacognition" means thinking about thinking. "Metacognitive strategies" enable people to apply attention management to new learning tasks, a higher-order form of cognition in which the thinker takes over active control of cognitive processes. It sounds dizzying, but reflective awareness of one's own thinking processes is the fundamental mind-tool, useful in mastering higher-order methodologies. Paying attention to their own attention has had a payoff for meditators for thousands of years, and modern neuroscientific research confirms the claims of meditative disciplines that the mind can be used to master the mind.

Note that learning about metacognition can lead to actually performing metacognition more effectively. "While there are several approaches to metacognitive instruction," writes Jennifer Livingston, professor of educational psychology at State University of New York, Buffalo, "the most effective involve providing the learner with both knowledge of cognitive processes and strategies (to be used as metacognitive knowledge), and experience or practice in using both cognitive and metacognitive strategies and evaluating the outcomes of their efforts (develops metacognitive regulation). Simply providing knowledge without experience or vice versa does not seem to be sufficient for the development of metacognitive control."[44]

Metacognition meets augmentation at multiple points, the most important of which are:

- *metacognition and online information-management (which I call "infotention")*[45]
    - *metacognition and use of search engines,*

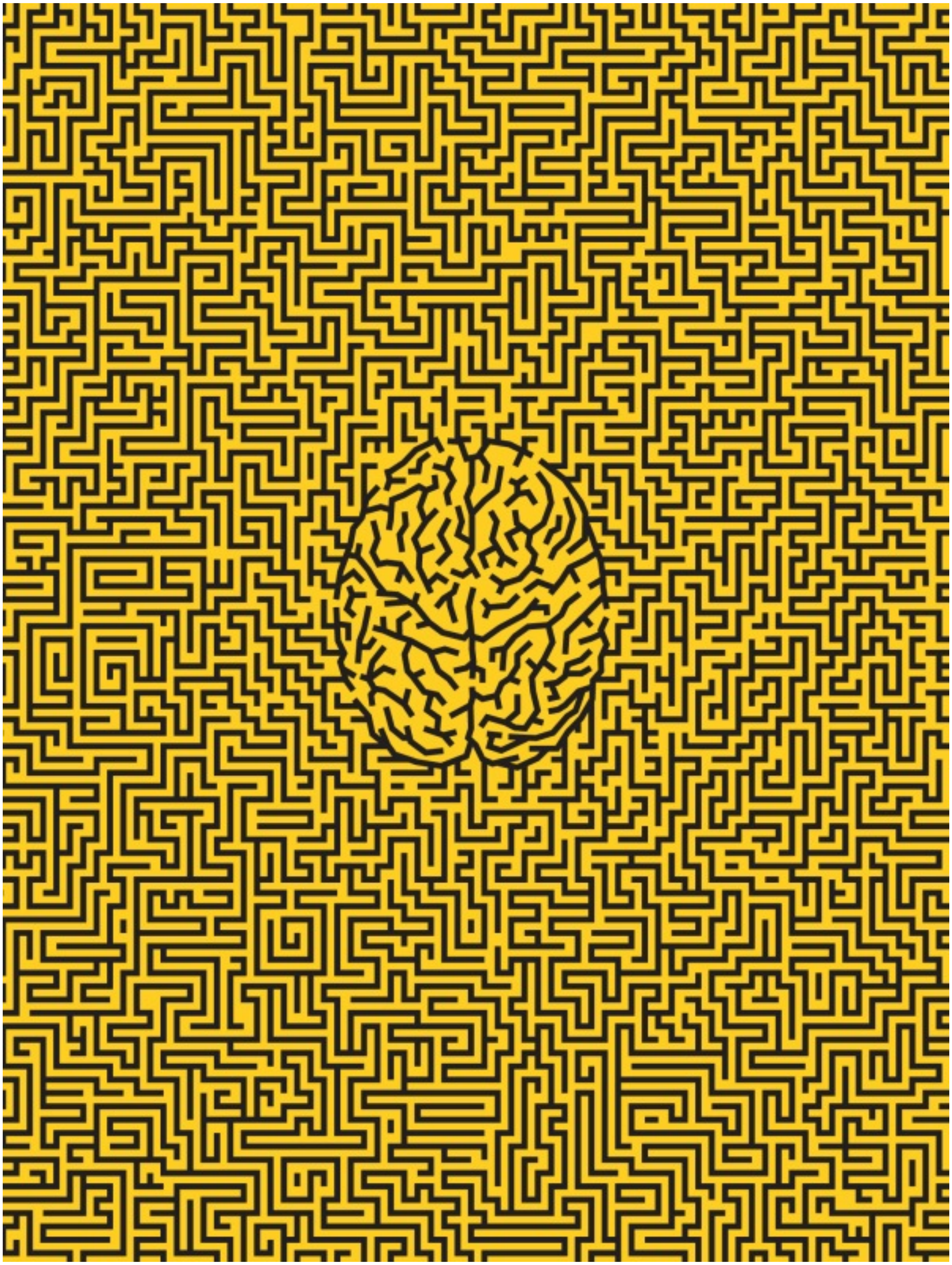
- *metacognition and critical consumption of information (what Ernest Hemingway called "crap detection").*

In my 2012 book *Net Smart,* I wrote that making one's priorities visible enables the establishment of new habits in the ways people control the flow of their attention online.[46] For example, every morning when I sit down in front of my computer, I write two or three goals for the day on a piece of paper and put it next to my computer screen, at the periphery of my vision; whenever I catch sight of the paper, I ask myself where my attention is directed at the moment and whether I am making progress toward the goals I wrote down that morning. With this practice I have established an inner observer, making me more aware of how I use my attention when sitting in front of my screen.

I also wrote that most people don't think twice about the everyday magic of search engines — if you come up with the right combination of words, you can get the answer to just about any question within a second or two, practically anywhere on earth. When the search engine shows you your answers, it's up to you to evaluate the veracity of what you've found. That's where crap detection comes in.

Crap detection, another emerging survival skill necessitated by the Web's destruction of the authority of printed texts, was also covered in *Net Smart*. I detailed efforts under way to design a hybrid of automated and social means for sifting the information that is useful from stale information, misinformation, and disinformation. Part of the process of effectively harnessing the power of search involves the metacognitive skill of regarding all digital information with a skeptical eye, searching for clues, and using social networks and online tools to test the validity of online "knowledge" found or sent to us. Such tools might be thought of as mind-extending lenses, bringing into focus the most trustworthy information while blurring the questionable information into the background.

If we need information lenses, we also need attention-reflecting tools. Could any aspects of the visual human-computer interface be used as reflectors of people's state of attention? The beginnings of research into the principles of augmenting metacognition are under way. A journal article titled "Toward Computer-Based Support of Metacognitive Skills," by computer science professors Cristina Conati at the University of British Colombia, and Kurt Vanlehn from Arizona State University, presented "a computational framework designed to improve learning from examples by supporting self-explanation — the process of clarifying and making more complete to oneself the solution of an example."[47] People solve mental problems and puzzles all the time without looking closely at how they did it; reflection upon and self-explanation of thinking processes is a metacognitive skill that the authors of this paper regard as computer-augmentable. What if automated tutoring and testing systems, such as those being deployed for Massive Open Online Courses (MOOCs), could be used for self-reflection on the learning process — a metacognition amplifier?[48]



Automating abstract thought

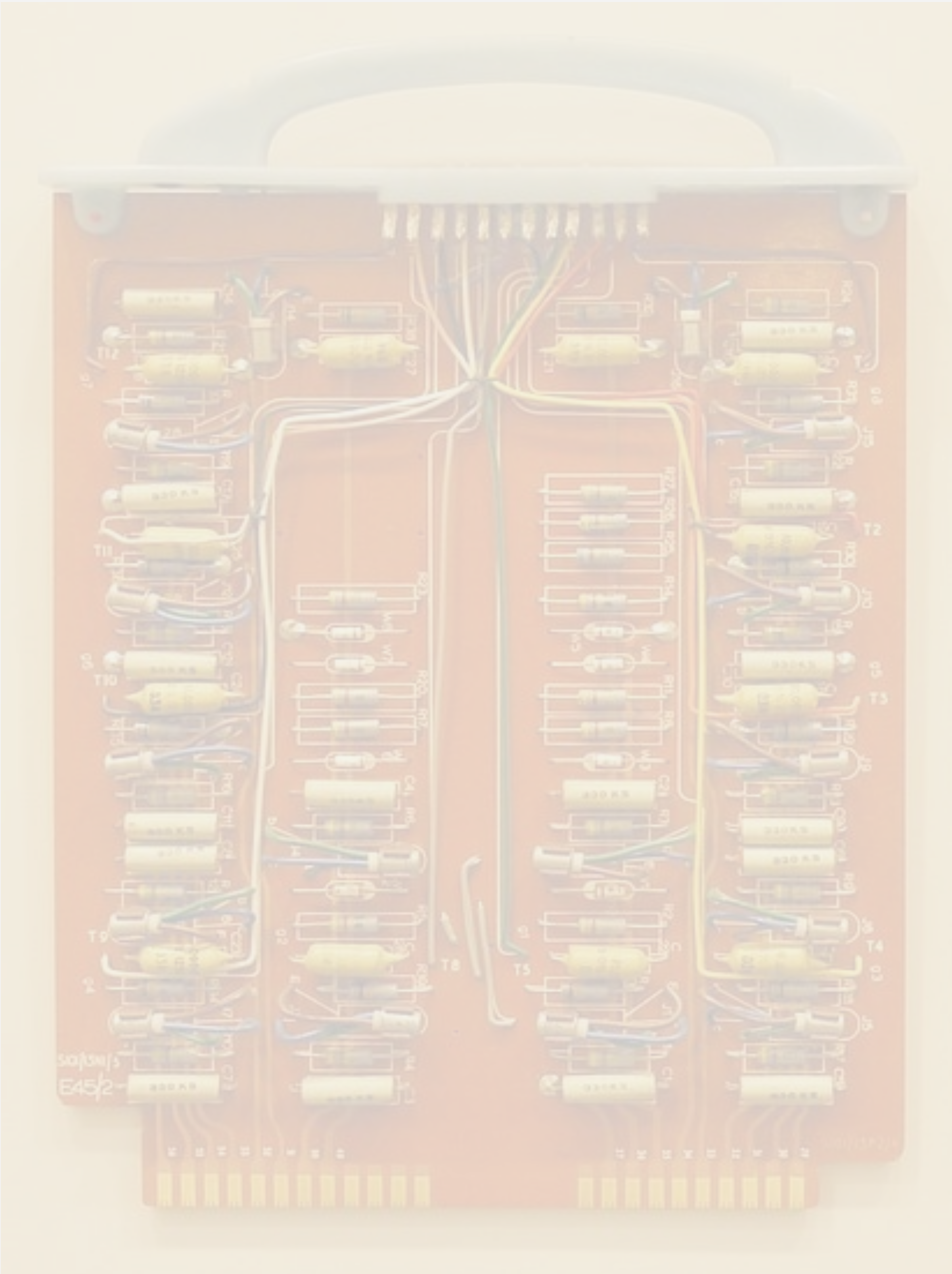
We use words and letters and ideas to pack a lot of information into small, portable packages. It started as a workaround for one of the apparent limitations of human thinking capabilities. The amount of information the (untrained) human brain is capable of holding in working memory appears to be limited, a constraint that we have transcended through the use of abstraction, a mind-tool that connects neural and computational means of information processing. The limits of human short-term memory were famously quantified by psychologist George Miller in his 1956 paper, "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information."[49] If an untrained human can hold about seven pieces of information in mind at once, then that limited information-holding capacity can be amplified by making each of those pieces of information symbolize a number of other things.

Abstraction — lumping, chunking, categorizing a number of simple concepts into a single, more complex concept (such as using the word "alphabet" to describe any collection of letters that serve as building blocks for words) — was one of the initial elements of culture (together with social learning, language, and mimesis). Learning to lump together the smell, sound, and sight of a tiger (memory of percepts) together with reasons to fear a tiger (memory of emotions) used the conceptual container provided by language to link to a single word all the different perceptions associated with all the actual tigers the learner has experienced.

Connecting the concept of tiger with the concepts of watering hole and sundown would have been a further, useful self-teaching device 100,000 years ago. Learning to convey to another person the notion of "tiger" through the use of gestures and audible utterances, perhaps picking up a stick to make a sketch of a sabertooth in the sand, not only multiplied the power of conceptual abstraction by attaching this mode of thought to a mode of communication, it introduced a powerful way to build mind-tools — abstracting abstraction. The idea of a tiger is represented conceptually in an individual mind, then abstracted to another level of symbolization by associating the concept with a human utterance. When clay accounting tokens morphed into writing, another level of abstraction was achieved — marks on clay (abstraction) represented a word (abstraction) associated with a specific utterance (abstraction) that evoked a specific person, place, thing, action, or concept.

While human brains are equipped to perform the mental operations necessary for nesting abstractions, humans are not born with fluency at abstraction. Like reading, the knack for piling up abstractions requires training, learning, and the use of cultural methodologies like mathematics or language. The power of the alphabet derives from the abstraction gymnastics it forces literate brains to undergo. Packing and unpacking nested meaning requires mental exercise: "This letter means that sound, and this combination of sounds symbolizes that thing." That exercise, in turn, reprograms the brain to perform more complex abstractions with greater rapidity by strengthening connections among networks of brain cells and organs. Think of how you needed to sound out words when you first learned to read, letter by letter, then trained your brain to recognize the word and directly evoke its meaning when reading.

When computers were introduced, the power of abstraction became automated — our physical devices, by assisting the nesting and remembering of abstractions, made it possible for our minds to do what they had not previously been able to do. Computers themselves are an unanticipated consequence of the search for a systematization of abstraction. Mathematician Alan Turing famously used the thought experiment that has become known as the Turing machine as part of a proof that mathematics could never be completely described by any logical system.[50] When John von Neumann and others connected Turing's imaginary machine with George Boole's algebra of logic and hitched them up to mechanical calculators, machines that could perform aspects of thought became possible.[51] When the physical tokens used for manipulating abstractions were first used to represent logical functions, and the logical functions were instantiated as an electrical circuit, the abstraction of abstraction became increasingly a human-machine process. The use of computers to solve human problems through the mediation of symbolic languages became a "fifth language," according to Logan, together with speech, the alphabet, mathematics, science, and printing. The use of Internet-based media, in Logan's view, is the sixth language.[52]



A circuit board from the LEO III, one of the first computers used for commercial business applications, in the 1950s.

Image: Creative Commons

An abstraction folds up multiple dimensions of meaning into a single token — a sound or mark or signal. The power of computation and of human-computer symbiosis derives from the particular way electronic circuits model logical equations, linking physical and cognitive mind-tools — logical operations using mechanical switches emulate procedures that previously had been purely mental, performing them by relays rather than neurons. When MIT and Bell Laboratories' scientist Claude Shannon demonstrated (in his Master's thesis!) that electrical switching networks like the telephone system could be configured to represent the logical elements of Boolean algebra — the mathematical foundation of automated decision-making — it became possible to devise machines that used other machines that used other machines to solve human problems.[53] A computer program is a virtual machine that directs the operation of the computer's hardwired virtual machine (its "firmware"). From the most fundamental physical level to the most sophisticated human-computer interface, your computer's hierarchy of abstractions chunks, piles up, and configures machine abstractions to make it easier for humans to apply the machines to our intellectual questions.

The question now is how to incorporate what is known about the psychology of attention, the reprogramming of the neuroplastic capacity of the human brain, the effects of human-computer interfaces, tools for turning complex data into visualizations, and the collaborative affordances of online media to deliberately design the next level of abstraction. For example, Engelbart's lab invented the outliner, a way to expand and collapse nested headings, available on personal computers since the earliest models. With one click, I can expand or contract the top-level chapter heading view from the heading-and-subheading view. I can nest levels of text under the headings and subheadings, thus visually climbing up and down hierarchies of abstraction with a few keystrokes. Abstraction isn't automated by outliners — it's controlled by a human and augmented by the computer outliner the human uses.

Human- and machine-aided abstraction are being opened into new realms by animated computer graphic visualizations that enable scientists and operators of complex systems to grasp the key patterns in voluminous and fast-moving data. Computers can quickly assemble models from large amounts of information; humans are so good at recognizing patterns that a great deal of the processing of visual information is computed by parts of the human visual system before it reaches the brain.[54] Visualization enables multidimensional forms of abstraction, just as outliners enable rapid ascent and descent of a one-dimensional hierarchy of abstraction. A purely graphical programming language, in which complex computer commands can be assembled by manipulating graphical symbols on a screen, has long been an unrealized goal. Richard Feynman famously forecast the rise of nanotechnology when he declared, "There's plenty of room at the bottom."[55] It's time to consider what technology we want to create using the autocatalysis of human pattern recognition, human-machine abstraction, and computer graphics modeling capabilities.

Collaborative cognition

I didn't count, but I wouldn't be surprised to learn I used Google several hundred times while writing this ebook. It's not just an outboard extension of my memory — it's a connection to the memory of everyone in the world (and I certainly have to do my own crap detection on what I find). I don't interact just with machines, but with people and networks of people.

For example, this morning I noticed a query on Twitter from an educator whose work had informed my own teaching. He wanted to know if storing cleaning supplies visibly in communal spaces encourages people to take more shared responsibility for cleaning. I tweeted back to him that I read somewhere that he could increase voluntary compliance by putting up a photograph of a pair of human eyes. But I couldn't remember where I had read about this effect. A minute later, someone else in the inquiring educator's network added to my tidbit of lore that the original study was done with a coffeepot — putting up a representation of eyes raised the amount of money people put into the coffee fund. That was enough information for me to look up an article about the research, titled "Don't Think I Don't See You," and send the URL to the educator, the educator's network of Twitter followers, and my own network of Twitter followers in one short tweet.[56]

Ed Chi, who ran the Augmented Social Cognition group at Palo Alto Research Center (where the point-and-click interface was invented, later to be appropriated by Apple and Microsoft), defines augmented social cognition as using media to "enhance a group's ability to remember, think, and reason."[57] I'm using the term as an even wider umbrella to include a variety of ways that groups and networks of people and machines can collaborate, including directing the production of physical goods and providing intangible but valuable emotional needs, such as a sense of belonging. When the human aptitude for mind-extension is plugged into specially designed computational mind-amplifiers and joined to one another through the many-to-many capabilities of networked media, new forms of social cognition begin to flourish. Many genres of augmented social cognition have emerged since Engelbart's time. Our vocabulary now includes "virtual communities," "smart mobs," "collective intelligences," and "social production." Knowing how to become part of these augmented collaborations and how to enlist others to join yours through networked media has become an empowering social skill for millions if not billions of people.

The design of computers to enhance cognitive functions of individuals becomes an order of magnitude more complicated when enhancing the cognitive functions of human social groups. Sociology, anthropology, social psychology, and economics join cognitive psychology, system engineering, software construction, and user interface design as essential parts of multidisciplinary augmentation design. (Engelbart knew this in the 1960s, when he brought a psychologist into the Augmentation Research Center.)[58] Those who seek to create new, powerful mind-extending technologies could benefit by analyzing and experimenting with the application of tools and techniques to multiply the power of collective intelligence and crowdsourcing.

Collective intelligence

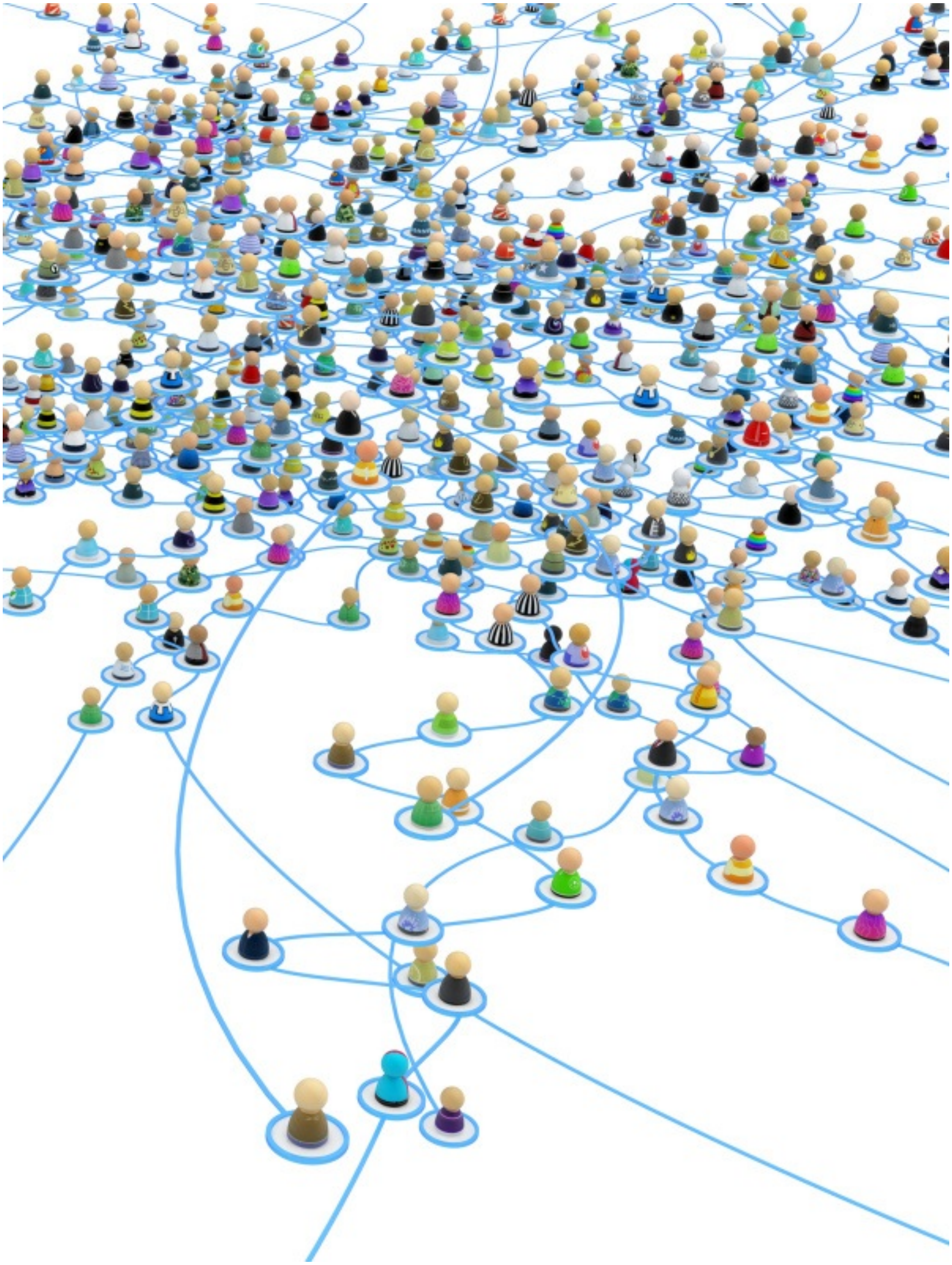
On a clear January day in 2007, computer scientist Jim Gray set out alone from San Francisco Bay in his sailboat to scatter his mother's ashes at sea. When he didn't return that night, his friends in the computer industry obtained the latest satellite photos from NASA of the 3,500 square miles of the Pacific where Gray might be found. Microsoft and Amazon engineers divided the photos into half a million smaller photos and thousands of volunteers unsuccessfully searched for Gray.[59] When hurricane Katrina dispersed families through the southern United States, the Katrina Peoplefinder Wiki sprang up to coordinate people's efforts to find their relatives.[60] Social bookmarking utilities and curation platforms enable individuals online to add their judgments about information to aggregations of knowledge available to all. The forms of collective intelligence springing up online are almost too numerous to list.

"Collective intelligence" refers to the myriad emerging ways that populations are putting together their individual brainpower and computing power via online networks to uncover and aggregate knowledge; crowdsourcing is a technique that is used for many other purposes as well, using computers and networks to divide tasks into small pieces and portioning out the work to large numbers of people. The hybrid of communicated collaboration and crowdsourcing, only a few years old, has produced prodigious results in diverse fields. Wikipedia is proof of the claim that networked, computer-equipped individuals can aggregate knowledge as a collective, voluntary enterprise. In China, they are known as "human flesh search engines" — online groups that divide the labor of sleuthing information among thousands of volunteers.[61]

The scientists around the world who tracked and succeeded in decoding the SARS virus used online media to work collaboratively around the clock as people in different time zones handed off to each other.[62] PatientsLikeMe, an online community for patients, families and caregivers, used its own data to publish its own clinical trial questioning the effectiveness of using lithium carbonate to slow the progress of the disease ALS.[63] Groups of Playstation gamers have pooled their game machines' computing power and their own gaming skills to help medical researchers understand how an important protein is physically configured.[64] During the Haiti earthquake, crisis mappers used a combination of text messaging and mapping to coordinate relief efforts — part of Crisis Mappers: The Humanitarian Technology Network.[65] In the U.K., citizens pored through nearly a quarter of a million expense reports to uncover fraud by members of Parliament.[66]

The study of collective intelligence proceeds on multiple fronts. Henry Jenkins has studied and written about collective intelligence in popular culture fan communities.[67] Tom Malone recently put together within MIT's Sloan School of Business the Center for Collective Intelligence, asking, "How can people and computers be connected so that — collectively — they act more intelligently than any individuals, groups, or computers have ever done before?"[68] The CCI is not just a think tank; it actively pursues empirical research. Its first report in the prestigious journal *Science* was widely cited for its evidence that diversity and the presence of women can raise the collective intelligence of groups in measured, controlled tests.[69] Research projects include attempts to harness collective intelligence to address the problem of global climate change, studies of "new, more powerful modes of knowledge management," and “nonlinear negotiation” that could “help large numbers of individuals come to agreements about complex problems with many interdependent issues.”[70]

What can mind-extension design learn from practical examples of online collective intelligence that continue to emerge and the multidisciplinary empirical study of collective intelligence? Any course on introductory mind extension should include a module on the empirical study and practical application of collective intelligence and crowdsourcing capabilities.



The power of many

Certain varieties of ant on the hunt for food deposit a trail of chemical signals, called pheromones, that are detectable by other ants also searching for nourishment. When an ant discovers food, it returns with it to the nest, laying down a sprinkling of pheromones as it goes. Other ants that stumble upon that chemical trail follow it to the food source. They then head directly back home to their colony, laying down more pheromones and reinforcing the strength of the chemical signals laid down by previous ants. As more ants follow the same trails to and from the food, their signals grow strong enough to attract even more ants from greater distances. When the food source is exhausted, ants stop following that trail and the chemical signals fade through evaporation.

Where does the intelligence of the ant colony reside? The nervous systems of the individual ants are too simple for the kind of deliberation performed by the human prefrontal cortex. But by overlaying signals on the environment, populations are able to perform collective computations that prove useful to the group. There's a word for this type of self-organizing behavior: *stigmergy*.

Stigmergy is the name for the way complex activities or structures can emerge without any kind of central planning and control. In this case, individual ants leave traces in the environment that coordinate, trigger, and channel further behavior by other ants.

Consider Wikipedia, an environment that triggers and coordinates behavior through traces that humans leave. Anyone can start an article (a “stub”), which automatically appears on a list of new articles, signaling other Wikipedians to inspect it. Editors can leave messages calling for a discussion of whether the article is appropriate, calling for further development, citation of sources, or other needs. While editors can and do argue on "talk" pages, the entire process is open to anyone who follows the signals and clicks the "edit" link.

Mark Elliott, a doctoral student at Victorian College of the Arts in Melbourne, Australia, laid out the case for stigmergy on Wikipedia in his thesis (I was one of his readers), describing it as a powerful form of behavioral-architectural design than can be applied to computer-mediated human collaboration.[71]

Google and the Web itself also exhibit stigmergic characteristics. (Think of links as the pheromones that Google's PageRank algorithm aggregates into search criteria and which the authors of Web pages use to interconnect ideas.)[72] The "swarm intelligence" of Google and the Web emerged after millions of individuals created Web pages and trails of links. This human-machine-network swarm intelligence wasn't specifically planned, although the architects of the Internet's original protocols designed a radically decentralized system that could be repurposed (exapted, in a way) by future innovators (the way Sir Tim Berners-Lee repurposed the Internet into the Web). Many (but not all) of the individual nodes of the Web are humans who bring considerable individual intelligence to the network.

Philosophers and extended-mind theorists David Chalmers and Andy Clark describe human-thinking-tool systems as closely integrated systems that resemble online stigmergy:

> *[T]he human organism is linked with an external entity in a two-way interaction, creating a coupled system that can be seen as a cognitive system in its own right. All the components in the system play an active causal role, and they jointly govern behavior in the same sort of way that cognition usually does. If we remove the external component*

the system's behavioral competence will drop, just as it would if we removed part of its brain. Our thesis is that this sort of coupled process counts equally well as a cognitive process, whether or not it is wholly in the head.[73]

Can deliberate and emergent behaviors be catalyzed, reinforced, and channeled with the help of personal media and vast, fast networks? Now that we have socio-technological use-cases, such as the Web and Wikipedia, with specific histories and observable design characteristics, is it possible to design stigmergic human-machine intelligence that does not yet exist?

A design for improved collective action

Beware of misapplying a powerful but limited tool that amplifies only one aspect of human character — the capacity for rational thought and symbolic communication. That was the fundamental lesson I took away from artificial-intelligence pioneer Joseph Weizenbaum's 1968 cautionary polemic *Computer Power and Human Reason: From Judgment to Calculation.*[74] Simply being able to reason more effectively is not only unlikely to improve the human condition in the absence of other, more humane capacities, Weizenbaum warned: it can do harm.

In the decades that have passed since Weizenbaum's warning, digital media have demonstrated their potential to lead to distraction, dehumanization, and delusion. Conversely, the same technologies also make possible enhanced thought, discovery of new knowledge, collaboration, and cooperation on unprecedented scales.

Perhaps we need to withdraw some attention from the older, simplistic arguments about technology as savior or demon and seek responses to digital immersion in terms that are not starkly positive or negative. I don't know if it can be done, but a socio-psychological practice of technology design that includes mindfulness and empathy might succeed where strictly instrumental approaches have fallen short.

My time as editor of *Whole Earth Review* introduced me to the great practical, radical philosopher of technology Ivan Illich, who made the a distinction between "convivial tools" and the kinds of technology that deaden, poison, dull, and imprison the human spirit. Such a distinction — which entails the possibility of bringing in other aspects of human character (compassion, for instance) into the design of tools — elevated the dialogue about technology beyond the Manichaean "utopia versus enslavement" arguments.[75] I would caution those who follow the directions pointed out in this book to keep both Weizenbaum and Illich in mind when building and using augmentation technologies.

Convivial tools, as Illich described them, require widespread knowledge of what the convivial tool does, how it works, and how to best use it for one's own purposes. In other words, a literacy. Digital networks afford the global, multimedia communications Licklider and Engelbart had envisioned. But the enhanced communication capability these networks have made possible has failed, so far, to disseminate digital literacy thoroughly among billions of Internet and smartphone users. Digital media and networks don't themselves teach people how to use them.

People learn by imitating others. The extraordinary growth of the Internet has outpaced the ability for norms and best practices to emerge as exemplars of productive behavior. As a result, only a fraction of those who have access to networked mind-amplifiers know how to use them convivially. One consequence of this mismatch between access and know-how is informational noise and personal attacks. Calls for more civility online have proved inadequate. What we need is communication design derived from a deeper understanding of how and why people use media to cooperate.

Engineers and technocrats have failed to solve critical global issues, such as hunger and lack of sanitation, because the gnarliest of these problems are psychological and political as well as technical and logistical. How would we redesign future communication tools for the social systems in which they are embedded if we weren't so ignorant about the reasons people choose — and fail to choose — cooperation over self-interest? Connecting the world's population through a network by which it has become possible for most people online to send messages to most other people is obviously not the last step. Enabling the users of mind-amplified networks to solve problems for each other is no longer strictly a communications-engineering problem.

Elinor Ostrom, a political scientist, won the Nobel Prize for economics in 2010 for her work on "institutions for collective action," the bundles of norms, laws, incentives, punishments, and communication rituals that enable people to do things together. Her book *Governing The Commons: The Evolution of Institutions for Collective Action* is an important text for anyone who wants to apply the mechanisms and methods of "augmenting human intellect" to social problem-solving.[76]

Ostrom's work grew out of her observations of populations that had to manage a common-pool resource, from police systems to water-sharing agreements. She challenged the dogma that the absence of top-down authoritarian control or private ownership always leads to the despoiling, overconsumption, or underprovisioning of common-pool resources — the well-known "Tragedy of the Commons." Ostrom offered a wealth of data from different nations and eras with numerous examples of people co-creating cultural institutions that enabled them to cooperate.

She demonstrated, through meticulous field research and inspection of public records, that a significant number of populations have been able to overcome "social dilemmas" — conflicting choices between acting in one's own self-interest and acting in concert with others.[77] Although game theorists and psychologists have elaborated on the integral role that conflicts, mistrust, and competing interests play in the affairs of many species, including our own, Ostrom established that people in different circumstances and cultures invent social workarounds for conflicts and create ways to share common resources.

Most important, Ostrom discovered eight design principles most often present when people succeed in collective action. These aren't meant to be turned into rigid prescripts for inducing cooperation, but they could be useful thinking tools for social-augmentation designers:

- *Group boundaries are clearly defined.*
- *Rules governing the use of collective goods are well matched to local needs and conditions.*
- *Most individuals affected by these rules can participate in modifying the rules.*
- *The rights of community members to devise their own rules is respected by external authorities.*
- *A system for monitoring members' behavior exists; the community members themselves undertake this monitoring.*
- *A graduated system of sanctions is used.*
- *Community members have access to low-cost conflict resolution mechanisms.*
- *For common-pool resources that are parts of larger systems: appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.*

Designers who want to succeed where their predecessors have failed should consider Engelbart, Illich, and Ostrom. Doing so is not a surefire formula for success. But at least it will provide a fresh perspective to see the world in a way other designers have thus far overlooked.

A place to begin

Metacognition, abstraction, augmented social cognition, collective intelligence, and stigmergic collaboration — all big ideas, and all are offered as likely entrances to mind-extension design. They're not an exhaustive list of ways that in and of themselves will provide us with better tools, but they are methods and ideas that could help people solve problems together using digital tools. They are a beginning.

And we do have problems. We have 7 billion people to feed. There aren't enough toilets to go around. Human activity may have already altered the Earth's climate in severe ways. Global travel and widespread use of antibiotics appear to be breeding emergent epidemics. Nations in conflict over land, water, religion, and/or ideology are arming themselves with nuclear weapons. We need problem-solving tools, among other things — as Vannevar Bush warned in 1945 and Engelbart detailed in the 1960s. Can these technologies help us develop digital tools that help us unknot these troubling problems? I think they can.

It is an enlightenment conceit that knowledge generates progress, that by knowing more about how the world works we can make it work to our advantage. Certainly we can now see that knowledge also generates problems. But just as microscopes and a biological understanding of microorganisms taught people to avoid illness by boiling their water, a more systemic understanding of the extended mind might teach us how to use our tools to preserve, rather than threaten, the continued survival of our species.

Faced with the challenge of severe environmental change, our forebears invented language and writing. It seems clear that we again face an inflection point in the history of our species at which better tools might make the difference between advancement and extinction.

It is time to design our digital tools more mindfully. They are and can be incredible problem solvers. And, as such, incredible changes await.

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