Your Stone Age Brain in the Screen Age

ALSO BY RICHARD E. CYTOWIC

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Your Stone Age Brain in the Screen Age

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For Stephen P. Gorman
In memoriam

And to the Virginia Center for the Creative Arts, where, as a ten-time Fellow over the past twenty years, I have worked amid the Appalachian foothills and been blessed with equal shares of camaraderie and silence.

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Preface: Your Stone Age Brain, 3 BCE versus Today

Ages ago, on the Tanzanian coast, sunrise: Aurora creeps over the African hills. Life begins to stir as the sky glows pink, then slowly brightens to blue. Nocturnal animals hunker down and daytime creatures awaken, including the prehuman precursor of *Homo sapiens*.

Kushim is the clan leader, the first to venture beyond the cave while the others hold back. The air smells sweet. Birds flutter overhead and warble in the trees. Kushim tilts his head to check the thrum of insects pulsating in the background. He hears the normal morning soundscape that he has come to anticipate. Anything unexpected—a nearby growl, an acrid smell, a haze of smoke in the wind—will instantly put him on alert without his having to think about it, and will spur him to signal danger to the rest of the clan.

There appears to be no danger this morning. So Kushim grunts the understood signal for kinfolk to come out into the clean morning air. His small band numbers about three dozen. The coming daylight hours hold much for them to do, all except the infants strapped to their mothers' backs. Mothers need their hands free to hunt and forage and augment the work the men will do. As the sun warms their faces and drives off the damp chill of the cave, five of the women head down to the water's edge, where they will gather clams and oysters. If lucky, they may catch a few shrimps in the tidal pools. Each day it takes enormous cooperation to feed everyone, and harmony is essential if the group hopes to survive. From dawn to dusk life is active, physically demanding, and requires the group to expend many calories that everyone must help replenish.

Three young girls tag along behind the older women. Leaders Irg and Uma wade with them into a tidal pool, one not too deep, so that they

can turn over rocks and see what creatures lurk beneath. Animals tend to emerge from their hiding places at slack tide. The girls must be quick if they hope to catch any. But first the women show them how to collect the plentiful sea urchins trapped along the bottom while avoiding a painful lesson from getting pricked or stepping clumsily on their sharp and sometimes poisonous spines.

Rocks close to the beach harbor abundant seaweeds and crustaceans. Periwinkles spend so much time out of the water that they are easiest to find. Blue mussels, snails, and sea lettuce are likewise easy to pick and deposit into the communal basket. If the girls are fortunate they will find a sea cucumber exposed. Rockweed, with its small air bladders at the tips of its fronds, is easy to spot, too. The salty seaweed can be chewed raw or used to wrap food into packets for roasting on hot stones around the fire, a newly discovered invention. Suddenly, something catches the corner of Irg's eye. "Ayiee!" she shouts to get the attention of a young one who has wandered off and is reaching for an outcropping that juts above the water line. Be careful of the razor-sharp barnacles: they can slice open your fingers, she mimes. An infection can be fatal, she warns, drawing an index finger across her throat.

Irg's orienting reflex has kicked in, one of the automatic circuits that, without conscious thought, effortlessly focus, shift, and sustain attention. Given the dangers lurking everywhere, an orienting reflex is essential to Stone Age survival. Irg had expected the youngster to be at her side still. Her peripheral vision, strongly connected to her emotional brain, swiftly registered the discrepancy, which goaded her to action. Often the orienting reflex is accompanied by a hormonal surge of adrenaline and norepinephrine that fuels the fight-or-flight response. Yet it is actually two pathways that throw the pre–*Homo sapiens* on alert. The first, quick pathway allows no time for deliberation, so that they jump at the stick they thought was a snake. Yet it is better to mistakenly jump than stand around deciding and succumb to a venomous bite. The second, slower pathway can override the quick one and allow time to consider a response (should I go right or left around that wildebeest I'm stalking?).

With infinite patience, Irg draws the girls to the center of the tide pool and shows them how striped shore crabs live under almost every rock. Up to thirty green crabs may cluster there, too, but within seconds they sprint to a new hiding place away from grasping hands. For her part, Uma points

out telltale bubbles that drift up from the sandy bottom. These mark the places where scallops have burrowed in during low tide. The women will come back another day to dig for them with shell scoops they have reserved just for that purpose.

The girls eye their elders carefully. It is common for group members to watch what others do, not out of suspicion but because imitation learning strengthens social cohesion. The whole community has a hand in child-rearing, reinforcing good behavior and dissuading the bad each time they mete out praise or disapproval. For every member, winning approval and the reassurance that one belongs strongly motivates behavior. Ostracism from the band would mean certain death.

Just then, another shriek. A sea slug has been spotted. This mollusk, which has no shell, is large, the size of two fists, and swims lazily in the quiet water. The creature hasn't any defenses and stands little chance of getting away. Into the basket it goes, getting the morning catch off to a good start and promising a tasty midday meal. Now if only they are lucky enough to find a baby lobster or octopus hiding under one of the tide pool rocks!

* * *

The menfolk have already departed before daybreak to hunt. Daybreak is when animals are most likely on the move, and early humans have now advanced up the food chain from scavenger to apex predator. Hunting provides ten times the energy return of a diet composed of fruits and plants. Carnivores throughout the Animal Kingdom have high stomach acidity that protects them from pathogens in rotting meat. Human stomach acid is higher even than that of such scavengers as vultures, hyenas, and coyotes, an adaptation that lets them consume large animals over a period of days or even weeks.

Kushim and kin are skilled at hunting in groups using sophisticated, close-range techniques with which they target carefully selected gazelles, wildebeests, and pronghorn antelopes. Mature antelopes are a favorite prey. Hunters sit in trees waiting to ambush a herd passing below, then spear them point-blank. After a successful kill they gut the animal with stone knives, tie it to a pole using vines, then haul it back to camp. The rest of the morning they spend butchering the kill while keeping a watchful eye out for opportunistic predators. The orienting reflex assures their vigilance because it renders the brain exquisitely sensitive to the slightest change

in conditions. The nervous system overall has evolved into one massive change detector because every novelty seizes its attention. The orienting reflex guarantees that sentries will turn toward and instantly judge whatever stimulus set it off, making them either freeze, flee, or attack. For now, things in camp are happily quiet.

Back from their excursion to the tide pools, the women stoke the fire and heat up the perimeter stones. They have become skilled at controlling fire not just for warmth but also to prepare food and fashion tools. Everyone lends a hand in replenishing the spears, knives, and stone tools on which the entire group depends. Unlike with chimpanzees, which live in aggressive, male-dominated societies with clear hierarchies, dominance does not shape social relations in early human collectives.[1] Each band, wherever it may have scattered, maximizes its survival because all members cooperate regardless of age or gender. Both genders are adept at creating symbolic art, too. Women dye and decorate marine shells while men build geometric sculptures from broken stalactites they haul from underground caves. Fostering harmony lets the collective function as a superorganism.

Besides time to make art, there is also time for games and play using objects at hand. Here is where the drive to compete becomes channeled in socially acceptable ways. Good-natured competition is rooted in emotion, and a fundamental basis of all emotion is comparison. Does someone have more than I do, or something desirable that I lack? This is the feeling that lies behind winning. Likewise, the fear of missing out or of being left behind rouses strong passions. And despite every effort of the group to maintain harmony, issues of hierarchy still threaten to arise. The group has conferred status on Kushim, Irg, and Uma because it acknowledges them as successful leaders. But no matter how egalitarian its intentions, wanting and pleasure remain forces rooted deep in the early human brain that can otherwise compel certain behaviors.

Unbeknownst to Irg and Kushim, many of their actions, such as snatching the young girl away from sharp barnacles or Kushim orchestrating other members in the hunt, are guided by molecules such as dopamine, a neurotransmitter that first evolved in much lower animals. In humans its functions are many because dopamine is the molecule that has a passport to every nook and cranny in the brain. Foremost in its dominion are reward and wanting, two basic instincts that lie behind survival and reproductive advantage. The impulse that pushes us to want is largely unconscious and

nearly impossible to satiate, which is why as soon as we get something we've wanted, we typically want something else. A related class of neurotransmitters comprises the endorphins, the brain's natural opioids, like those released during the runner's high or while chasing a gazelle across the savannah. Compared to dopamine, the opioids' range is smaller, they are harder to activate, and the satisfaction they provide is shorter-lived.

Stone Age humans are highly sensitive not only to wanting and reward but also to reinforcement, nature's way of perpetuating desirable behaviors. Food, water, sex, and shelter are primary reinforcers because they satisfy strong biological desires. As the *Homo* species evolves, their secondary reinforcers have become more diverse and sophisticated, as in the case of child rearing or teaching the younger members to gather, hunt, maintain the fire, and fashion useful tools. Reinforcement is not a tangible thing but a relationship between a behavior and whatever propagates it. Reinforcement leads to habits good and bad, which then become established as part of larger cultural traditions.

The sun now stands directly overhead, marking noon. Time to rest and eat what the gatherers and hunters have secured, the group's first intake of calories since awakening in the cave. Settled routines like this make the contours of human life predictable, and familiar repetition instills a sense of calm. Yet paradoxically, the experience of daily life is one of continual change, sometimes slow, at other times sudden. Many established routines are dictated by the Sun. Special light receptors in the retina that adjust the brain clock are especially sensitive to short wavelengths. Short blue wavelengths best penetrate the ocean, where all life began and where the photosensor first evolved before making its way to land creatures.

Later on, as daylight fades, it will yet again be time to wind down and sleep. In the morning, when dawn once again approaches, one set of hormones will signal it is time to wake up. For now another set, one that includes melatonin, start to surge in the bloodstream to signal it is time to bed down for the night. During the first part of the night slow brain waves predominate and the most restorative phase of sleep takes place. These are the golden hours, when everything the clan, especially its youngsters, has learned during the day is consolidated and transferred from short-term to long-term memory. This "first sleep" lasts until about midnight. when members awaken to engage in activities like sex, games, storytelling, or stoking the fire. Then body temperature falls, triggering a "second sleep"

that lasts until dawn. The pattern repeats itself naturally, season after season, without cease.

* * *

Three million years later: These basic survival mechanisms are now a door into modern brains that tech companies exploit for profit and competitive advantage. They hack our biology and hook us on their products because the brain hasn't changed since the Stone Age, let alone during the mere thirty-three years that the internet has been around. The story of why we are helplessly distractible began long ago, which is why the screen age feels like it has been with us forever. It certainly feels as though the digital devices that surround us day and night are part of an embedded iSelf, so much a part of us as to essentially constitute a planetwide hive mind like that of the Borg in *Star Trek*.

This is the predicament of the Stone Age brain in the screen age. The following pages explain Why you are so addicted to your screen devices, What you can do to push back against these forces, and How to go about it.

* * *

Your brain has been thoroughly conditioned by digital devices. Links, "likes," and "follow" buttons are so easy to click on that doing so has become a mindless reflex.

It is not your fault: companies employ reams of psychologists and behavioral scientists whose job it is to exploit the Stone Age brain's built-in vulnerabilities, especially its inability to ignore novelty and any change in prevailing conditions. Before the pandemic, one-third of the world's population spent the better part of a day fixated on a TV screen, a computer screen, or a phone or tablet screen—sometimes all three at once. Those numbers have since burgeoned. During the two years of pandemic-related lockdowns our closest relationships revolved around digital devices. We TikToked, Zoomed, swiped, and FaceTimed. On March 29, 2020, Tinder set a record of three billion swipes in a day. It then broke that record 130 more times by the end of the year, or once every two days.[2]

What can one say in defense of this riotous growth in digital engagement? Users do not appreciate how heavy an energy cost screen distractions exact on their Stone Age brain, which biology limits by the fixed amount of energy it has available. The cognitive load imposed by screen

devices degrades attention, memory, and thinking, along with sleep, mood, and concentration. The screens we habitually gaze into compete with and substitute themselves for our otherwise natural drive to socialize. They confront us with highly unnatural gambits for attention that we are nearly helpless to resist.

To prove that the urge to connect is not merely a social custom, fMRI measurements that simultaneously record from two individuals lying in separate but linked scanners illustrate a basic biological impulse to connect with one another. Brains in close proximity literally synchronize, just as the ending of *The Matrix Resurrections* film illustrates. It is this kind of fundamental coupling that smart screens interfere with.[3]

The coronavirus pandemic showed how hard it is to wrest digital devices away from kids of all ages. What started as a servant to those working from home quickly became the master. People increasingly began to realize that social media had given birth to a force their creators neither understood nor could control. While smart devices do bestow benefits, they are still narcotizing agents. So easily do they hack our neurological defenses that the forces behind them don't even need to hide their agenda.

From the brain's perspective, I ask: How much energy does the deluge of texts, alerts, and push notifications exact from the limited stock we have? And why did nature give us a limited stock to begin with? What consequences follow from the nonchalance with which we shove screens in front of a child's developing central vision and willfully ignore how iPads mounted in bassinets, car seats, and potty trainers displace that child's natural inclination to socialize?

I use the term "Stone Age brain" because we have the exact same biological organ as our long ago ancestors. Brain circuits operate at dramatically lower speeds compared to their electronic counterparts. No amount of diet, exercise, Sudoku puzzles, meditation, or yoga can increase what we have to work with. We can only affect how we manage it, and how we do that determines its efficiency. We face the same challenge as our distant ancestors of how to marshal and apportion the energy needed for thinking, acting, feeling, imagining, anticipating, and most of all paying attention to what's going on around us.

The brain accounts for a mere 2 percent of the body's mass but consumes 20 percent of the daily calories we ingest. The adolescent brain consumes 50 percent and the infant brain 60 percent, which is why the young are

disproportionately affected by heavy screen exposure. Adjusted for body mass and fat content, babies between the ages of nine and fifteen months expend 50 percent more energy in a day than adults do. This likely fuels their growing brain and immune system. In older individuals too, mental exertion has an energy cost. In one experiment a student burned 40 percent more energy during a math test and 30 percent more during a tough interview. It is hard to think of any other process that exacts energy consumption by anywhere near 40 percent.[4] At any age, the costliest things we can do in terms of energy expenditure are shift, focus, and sustain attention—a cycle that digital devices force us to endlessly repeat as if circling a drain.

The brain achieves its remarkable feats using only a few watts of energy—the equivalent of a dim light bulb. Most of it goes toward keeping up the physical structure by pumping sodium and potassium ions across membranes to maintain its electrical charge. Little remains left for thought, feeling, or action. Precisely because the brain is so efficient, its reserve margins are slim and eaten up by the demands made by constantly shifting the focus of attention. Think in terms of a budget whose currency is all the molecules that sustain our 86 billion neurons. As with financial budgets, we can run a deficit and go into the red. The brain must then terminate metabolic processes that are too expensive, resulting in mental fatigue, reduced focus, patchy memory, and errors.[5] Screens act like secondhand smoke, affecting anyone in the line of sight. Even the mere presence of a phone drains us because trying not to look at it sucks up energy, too.

One specter in today's screen-heavy environment is "virtual autism," the induction of autism-like behaviors in otherwise healthy individuals especially the young who spend many of their waking hours online. (I must stress this distinction between developmental autism and similar-looking autistic behavior caused by something else, and I discuss it at length later on.) Only recently have peer-reviewed studies begun to question the causal connection between the two as they tease out the similarities between developmental autism (now thirty times more common than it was in 1960) and the newly evident virtual kind. In both, social media compete with in-person engagement and interfere with the development of emotional circuits necessary to read other people. In both varieties of autism, affected individuals studiously avoid eye contact and bungle social interactions because they fail to grasp the meaning behind body language.

What matters more than having 86 billion brain cells is the ceaseless interweaving and rewiring of connections among them, a lifelong process known as plasticity, a word derived from the Greek *plastikos* (πλαστικός), meaning "capable of being molded." The brain absorbs experience from birth onward, plastically molding the organ's structure and function in response to its experience of the world. Our twenty-first-century mindset is itself trapped in the immediate present, in need of constant stimulation, and giving it too much early screen exposure looks to have terrible unforeseen effects. Ubiquitous screens promote sensation at the expense of thought because amped-up sensory pathways compete with the maturation of other pathways normally destined to support social relationships and emotional intelligence. Developmental autism never improves spontaneously during early childhood, but children with virtual autism do show dramatic improvements once digital screens are taken away.

Continual touchscreen use almost certainly reshapes the brain. Clever research records that subjects make up to 40,000 finger swipes a day, even while supposedly asleep(!). Merely swiping a screen rewrites the hand's representation in the brain's sensory cortex. The latter adapts and shrinks to become more efficient, meaning that our devices fiendishly habituate us to sensory overload. When more than 50 percent of first graders have smartphones, why are we not discussing these scenarios when an innocuous-looking swipe that physically reshapes the brain may also be permanently changing that individual's psychology and temperament?

We live in a paradox in which digital tech alleviates some social isolation even as it worsens it in other ways. We are technologically more connected than ever before yet bond on platforms engineered to make outrage and indignation infectious. They exploit the psychological principle that emotion, like yawning, is highly contagious. Raw emotion allows for neither nuance nor complexity, but it easily overwhelms critical thinking and leaves us swayed by propaganda and manipulation that is hard to recognize for what it is.

Two fashionable phrases in education circles are "critical thinking" and "connecting the dots." But surfing the internet encourages shallow gulps of the data stream, not critical thinking, while offloading factoids to external apps like Google leaves users with little common knowledge and thus few dots to connect. A mind capable of ascertaining connections thrives on

quiet, not on endless texts and notifications. There is a reason the natural world is easy on the eyes and ears, yet we cut ourselves off from its restorative power, forgetting that the brain, the psyche, and the soul need rest and uninterrupted interludes rather than streaks, autoplay, and push notifications that turn friendships and achievements into ruthless competitions.

The Latin word *addictum* once described the length of time an indentured slave, or addict, had to serve their master. The word's root means "bound to." And are we not bound like slaves to the screens in front of us? If not, then why do so many people claim to be addicted?

1

Engineered Addiction: Brain Drain and "Virtual" Autism

In one of my columns for *Psychology Today* I discussed different ways smart screens negatively affect the brain. To my surprise, anxious parents and grandparents from around the world wrote in to share stories of the detrimental effects that smartphones, tablets, and televisions seemed to be having on their families. A father from as far away as Iran wrote:

> We have a boy 13 month old. Unfortunately we letted him to watch TV and mobile app. Compared to other baby, he was different. He does not respond to his name. When I come home from work, he didn't pay attention to me especially while watching TV and apps. He had little eye contact and didn't hug me and his mother too.[1]

Concerned readers wrote that kids who once enjoyed sports, socializing with friends, and spending time outdoors were now glued to their devices for hours on end. As time spent on screens expanded, their ability to communicate seemed to wane. Once bright, loquacious youngsters now answered questions in grunts if they answered at all. They wouldn't look up, and acted irritated. Frustrated, even scared, by shrinking attention spans and the tantrums that ensued if they tried to take a device away, parents began to wonder whether the tools they once thought of as educational were instead turning their kids into zombified addicts.

I decided to look into it. A plethora of books talk about screen dependency, but few, if any, explore the topic from the brain's point of view—particularly the energy drain that screens enforce in the face of the fixed limits biology has placed on it. Why do I choose this perspective? Because the energy cost of any given process, whether biological or mechanical, is a fundamental aspect of engineering and thermodynamics. That's why biomedical engineering is called engineering and not simply mechanics.

It is why, out of so many effects that screens have on the human brain, energy consumption must be a paramount consideration. The existing literature doesn't address the question because hardly any of the authors have backgrounds in engineering or biochemistry, disciplines in which questioning energy costs are routine. The absence doesn't mean that the issue isn't worth discussing but rather that it is an unappreciated omission.

Almost everyone agrees that attention spans have collectively gone to hell. Worried parents are just one group that questions the influence of today's technology on the ability to reason clearly. Does the internet weaken memory by relieving us of the need to learn phone numbers, multiplication tables, and detailed facts, or does it enhance intelligence by placing millions of factoids at our fingertips? Do social apps bring us closer together or do they isolate us and turn what used to be two-way conversations into public performances ripe for outrage and moral grandstanding? Are screen-based devices addictive, and do they really induce autism-like symptoms, especially in young users? I will come back to this question.

In *Reader, Come Home,* literary scholar Maryanne Wolf blames screen addiction for the loss of deep reading ability.[2] Senator Ben Sasse, who holds a doctorate in history from Yale, says flat out that we are "addicted to distraction," while popular neuroscientist Daniel Levitin says that "multitasking creates a dopamine-addiction feedback loop, effectively rewarding the brain for losing focus and constantly searching for external stimulation."[3] We live a paradox in which digital tech alleviates social isolation in some ways even as it worsens it in others.

* * *

In addition to writing "The Fallible Mind" column for *Psychology Today*, I am a neurologist, a teaching professor at George Washington University School of Medicine and Health Sciences, and an author of neuropsychology textbooks and popular works. Until now I have largely been known as the person who restored synesthesia to mainstream science. Sharing a root with anesthesia, meaning "no sensation," *synesthesia* means "joined sensation." Four percent of the world's population are born with two or more senses hooked together so that otherwise normal individuals not only hear music or someone's voice, for example, but simultaneously see it, taste it, or feel it as a physical touch. Perceiving the days of the week, the alphabet, or numerals as colored is a common manifestation, as is tasting words or

seeing calendar configurations hovering around the body in space. These extra perceptions aid recall, endowing synesthetic individuals with measurably superior, sometimes photographic memories (technically called "eidetic"). When I explored my first synesthetic subject in 1979, my neurology colleagues immediately asked where the lesion was on his CT scan.

"No, you don't get it," I told them. "He doesn't have a hole in his head, a missing piece. He has something extra."

They looked at me like I was crazy and warned me to drop the matter as "too weird, too New Age." If I persisted in pursuing it, they warned, "it will ruin your career."

I spent the next fifteen years countering naysayers who insisted that synesthesia was bogus and couldn't possibly be rooted in the brain. It is the nature of orthodoxy no matter what the profession to dismiss or explain away what it cannot or does not wish to understand. Time has proven synesthesia to be a perceptual trait, like having perfect pitch; you either have it or you don't, and you cannot learn it through practice. My persistence in trying to understand this offbeat but fascinating human trait eventually brought about a paradigm shift in the way science conceives the brain's configuration and how perception works.[4] For years now, young scientists have happily been writing papers, books, and PhD theses about this once forgotten trait.

In other words, it didn't ruin my career.

Science is full of exceptions to established thinking. Take leeches, the application of which was once considered standard medical practice but is now mocked.[5] Who is to say that today's standards might not be dismissed as tomorrow's leeches? We have embraced smartphones and tablets as near magical tools that promise unparalleled productivity, connectedness, and opportunities for learning. Digital devices are indeed fantastic—Uber coming to your door in a minute is magic; GPS is magic; the ability to reach across time and span enormous distances is magic.

But for all its wondrous utility, the smart screen is also a narcotizing agent. What if it has unintended, possibly harmful, side effects? Since 2016 the American Academy of Pediatrics (AAP) has recommended no screen time other than video chatting for children two years and under, and only one hour of exposure in the presence of a parent for children two to five years old, with the caveat that "less is better." The priority for young children should be face-to-face communication, physical activity, and sleep

because their brains are changing in the most complicated ways. Yet given how rapidly screen intrusion is encroaching on otherwise normal development, the AAP is updating its guidelines, while the guidelines of the World Health Organization (WHO) stress no or limited screen time for children under five. Additionally, the NIH has launched a $300 million investigation into the cognitive development of screen-saturated youngsters from adolescence to young adult.[6] Pediatrician David Hill, who oversaw the AAP guideline revisions, says that the WHO is simply "applying the precautionary principle. If we don't know that screens are good and there is reason to believe it's bad, then why do it?"

The growing pool of readers who took the time to write forced me to question popular assumptions about screen media and its influences. I set aside synesthesia to explore whether screen media actually do have a detrimental effect on the brain, and if so, how. Two things immediately stood out. Screens of any sort act like secondhand smoke, affecting both the user and anyone within range, and screen exposure relatively easily induces "virtual autism," the emergence of autistic like behaviors in otherwise healthy individuals.[7] The father quoted above spoke to this and the apparent resolution of symptoms that followed screen removal:

> A psychologist told us we have to turn off TV and other screen and play with him. We now see the result. When I come home, he come to me and ask me to pick him up from ground. He hug wife and me. When we call his name he turn his face better than before, but still . . . we are worried for his future. Would you help us and advise us please?

An American woman contacted me about her thirty-month-old grandson, Parker, who wouldn't look anyone in the eye or respond to his name. He was under evaluation for autism spectrum disorder at the time when she wrote:

> He was exposed to almost constant children's "learning" programs on TV, tech toys that teach, and computer and phone games for most of his waking hours. We enrolled him in a day care two days a week for socialization. At the same time, I read about virtual autism, and we removed all electronic toys, phone play, and all children's TV from his environment.
>
> I believe the screen time and electronics really hurt his development. Now we play kitchen, coloring, puzzles, blocks, and other imagination and occupational games. Within 2 weeks, he was responding

Figure 1.1
Parker, age thirty months. *Left,* Before the ban on screens, he has a vacant stare and is unresponsive to his name being called. *Right,* Eleven weeks after screens were banned he smiles, looks at the camera, and "looks at the person talking to him," according to his grandmother. "He discovered his baby sister, too. He now looks at her and plays with her." Courtesy of Claire Thies.

most of the time to his name and looking at the person talking to him. I thought you'd be interested in our progress since removing "screens." It's 11 weeks and progressing every day (figure 1.1).

Finally, the head social worker for Chicago Public Schools wrote:

I work with children on a daily basis who are spending the vast majority of their waking hours exposed to media/screens. Parents are concerned about sleep disruptions, difficulty with emotional regulation

> and tantrums when access to technology is denied or removed. I read your article . . . and am working to inform parents on the connection between deficits in social functioning and the amount of time spent on screens.[8]

I'd like to say a few words about the critics, mostly academics, who think that "an unnecessarily negative view of screens" risks instilling "misplaced worries about digital technology."[9] They accuse anyone who advises caution of being one-sided and selective in the evidence they pick to support claims about the potential dangers of excessive screen exposure. Cautionary voices are guilty of scaremongering, they say, while categorically denying that virtual autism has anything to do with screens. Critics object that the rationale for restricting use isn't particularly grounded in solid evidence.

I heartily disagree. I am a clinician, meaning that by training I take a view centered on the care of the individual patient compared to the tut-tut of academics who mutter "there is no convincing evidence" while safely distancing themselves from having to deal with zombified kids and young adults. They don't have to deal with distraught parents or battle a two-year-old who shrieks and fights when you try to take away their iPad. The academics tell those parents, "there is no convincing evidence." To parents, however, the evidence is in front of their eyes. Yet naysayers continue to insist that the alarming behavior observed is due to something else, anything else, except the screens that young people refuse to relinquish.

How is it scaremongering to acknowledge parental alarm? It is parents and educators and addicted individuals themselves who sought my attention. None of them said "Give me more." Parents didn't write about how pleased they were that their offspring were spending the majority of their waking hours in front of a screen. On the contrary: I have heard many kids, even medical students, complain "I'm addicted to my phone." No one says "I need to use my phone, and my tablet, and my laptop a lot more than I do now." The benefits of digital technology are obvious; you don't need academic studies to convince anyone. But the downsides are also obvious if you are just willing to look.

There is some truth to the observation that once critical and in-depth studies of any new technology have been done, a revised point of view comes into shape that is different from the initial one. The iPhone has been with us since 2007, the iPad since 2010, but complaints of digital distractions are not diminishing. They are getting worse, as reflected in the feedback from users themselves, particularly students.[10] Yet naysaying

tech enthusiasts still want everyone to wait for "more evidence." A call for more research sounds well meant, but it is calculated to silence dissent from the Panglossian view that screen technology is nothing to worry about. It dismisses the precautionary principle out of hand and misrepresents the concept of evidence-based medicine. Those who insist on "more research" want science to be perfect. But science has limitations in trying to deal with the complexities of the real world and so can never arrive at "definitive proof" for multifactorial behavior that spans multiple disciplines. If we wait for the evidence that critics insist on, we will be waiting forever.

* * *

From my neurological point of view, the online world is one of hyperstimulation, not a paradise of risk-free beneficence. Ray Bradbury's totalitarian classic, *Fahrenheit 451,* depicts a world destroyed by overstimulation. Its protagonist, Guy Montag, a "fireman" whose job it is to burn forbidden books, lives with his wife in a digitally stimulated hedonistic bubble that constitutes the totality of their home life. COVID-19 lockdowns felt a bit like this as Zoom fatigue set in and the shift to life-on-screen drove people stir-crazy. Overwhelmed parents struggled to work from home. School-less, camp-less, and vacation-less kids, already obsessed with their screens, now had unlimited time with them. They gorged on YouTube and TikTok, surfing late into the night and sleeping away the day.

Paradoxically, in the midst of this bustle, adults had an opportunity to feel what they had been missing, namely, a less hurried life and time to think. COVID-19 forced us to slow down. It gave us still periods in which to reflect, to think about who we are, what we want, and what matters. Alan Lightman's *In Praise of Wasting Time* champions this kind of unstructured time for its "replenishment of mind that comes from doing nothing in particular." The mind needs stretches of calm. Creativity thrives in it. In Italy, quarantined citizens sang from their balconies each evening, their serenade reaching across empty streets to lift their neighbor's spirits. Opera, Broadway, regional orchestras, and pop musicians ingeniously stitched together coordinated online performances from far-flung participants.

Illustrating the downside were adults accustomed to noisy streets, constant demands for their attention, and a hectic lifestyle without a minute to be wasted. The unstoppable tempo of being busy is a stimulant, like nonstop caffeine and equally pernicious, gnawing away just when you have a moment to yourself. Suddenly alone with their thoughts, these folks didn't

like it. People who couldn't sit down in a restaurant without whipping out their phone or alight quietly anywhere for ten minutes suddenly had to confront silence and tolerate stillness—a new experience.

As a neurologist, I approach screen distractions from the perspective of energy consumption. It forces me to account for biological costs in terms of energy expenditure when engaging in a mental task such as committing something to memory and retrieving it later on. Other costly tasks include the executive weighing of options by the frontal lobes and arriving at a decision; switching back and forth from one frame of mind to another, as we do in multitasking; or juggling interruptions and competing demands for our attention. These led me to see that excessive use of digital screens is a bad deal when appraised from a basic energy perspective.

Let me be clear: I am neither a tech cheerleader nor a Luddite. Digital devices unquestionably make life easier. By serving as memory repositories, they put calendars, phone numbers, and contact information at my fingertips. Synchronization among devices is a godsend if I need something at home from my workplace or vice versa. Likewise, time zones are no longer a problem when communicating with far-flung colleagues and friends. An encyclopedia of facts sits at my fingertips (assuming I know what facts I even want to know). Amateur musicians turn to YouTube for lessons or lyrics; cooks, golfers, and weightlifters turn to the web for tips. GPS keeps me from getting lost, and map apps make it easy to explore and find my way, as well as discover eateries, gas stations, and local attractions. Screens have expanded written language even though that language may be immature, provocative, or just plain stupid. At the same time, the omnipresence of screens has left many exhausted, depressed, and lonely. "If you do not cultivate a capacity to think, imagine, and create," warns Adam Garfinkle, editor of the *American Interest,* "you therefore may not realize that anything more satisfying than a video game even exists."[11]

Michael Crichton, author of *The Andromeda Strain*, *Jurassic Park*, and *Westworld,* among other cautionary tales about the unintended effects of technology, held a medical degree from Harvard and had hands-on scientific experience in the lab. His techno-thrillers often portray scientific advancements gone awry, culminating in catastrophe. Dr. Crichton complained, however, that others frequently misunderstood his view of technology as "being out there, doing bad things to us people, like we're inside the circle of covered wagons and technology is out there firing arrows at

us." Technological catastrophes exist not because technology is inherently bad, he said, but because "people didn't design [it] right."[12] And, perhaps, too, because we don't use it thoughtfully.

Like Dr. Crichton, I aim to put forth evidence for the neurological consequences of excessive screen exposure and the costs of screen distractions. Tech titans have gone to great lengths to commandeer the fixed slice of attention our Stone Age brains have to work with. We are up against brilliant software engineers armed with personal data gathered through relentless surveillance and determined to capture our attention for commercial ends. They are better at distracting us than we are at defending the inherent weaknesses of our biology.

Not only have tech titans done a great job in vying for our attention, but they have also excelled at convincing us of the advantages of their products. With everyone blathering about supposed benefits, few mainstream media bother even to consider the potential negatives of this increasingly prevalent element of daily life. I am not saying that digital technology is bad, but in light of how it dominates everyday life, I suggest we examine its downside. Think of how often a traffic light turns green but the driver in front of you is buried in their phone, forcing you to honk the horn. Or how often you have to wait for a machine at the gym while the user finishes texting. Or how, when the power goes out from a storm, you put down your devices, venture outside, and speak to your neighbors.

Imagine that, for a change, you have promised yourself a good night's sleep. You've eaten dinner, changed out of your work clothes, gathered your things for tomorrow, and brushed your teeth. Before turning in, however, you decide to relax by streaming a show on Netflix. Ignorant of your intention to catch up on sleep, Netflix's "next episode in 5 seconds" and "skip intro" features keep you anchored to the screen. Before you know it you have binge-watched half a dozen episodes because streaming companies need you to do so in order to make money. YouTube's "next up" and "auto play" algorithms likewise analyze your viewing history. With a sniper's precision they target you based on what they infer from the online choices you have made.

Companies effortlessly unscramble purportedly anonymous metadata to trace your entire online transaction history using just three pieces of information: two physical locations and a dollar amount spent.[13] Facebook and Google own some of the fastest machine learning supercomputers on

Earth, so this has become easy to do.[14] As far back as 2012 Uber could examine user patterns to identify intimate behaviors such as one-night stands.[15] Companies insist that the details they sweep up are anonymous, but they can track your movements to within a few yards. Even particular items we buy can predict our political beliefs, race, and education with frightening accuracy.[16] Privacy is nearly impossible now thanks to "data inference" technology.[17]

Tech giants know everything about you, including your mood, whether you're lonely, anxious, excited, or depressed. They know where you shop, where you go, the online sites you visit, how long you hover there, and much more. Their artificial intelligence (AI) learning machines build models based on everything they gather about you to predict what you are going to do next. The recent integration of ChatGPT, Bing, and similar chatbots into browsers and operating systems will give them even more data about you. Armed with that knowledge, they then try to sway you to do what they want you to do. It will be one or all of three things:

- Keep you engaged as long as possible.
- Invite friends to do what you are doing online, called growth hacking, which multiplies your influence and thus increases their revenue.
- Respond to advertising offered up as you endlessly scroll, with the end goal of all manipulations being always to maximize profits. Since 2006 Facebook has had a director of monetization who offers software to its advertisers to do exactly this.

Shoshana Zuboff, emerita Harvard Business School professor and author of *The Age of Surveillance Capitalism*, says "trading on human futures" earns trillions of dollars. By exploiting vulnerabilities in human psychology, tech giants "trigger real-world behavior and emotions without the user ever being aware. They are completely clueless."[18]

The industry's earliest backers and engineers are now among its fiercest critics, angry that the platforms refuse to confront their product's addictiveness and treat our minds as an extractable resource no different than if they were operating an open pit mine. These critics lament the deceptive attitude that social media are "free," citing the adage that if something is free, then you are most certainly the product on sale. That is true to a point, but Jaron Lanier, father of virtual reality, ominously warns what the product really is: "the gradual, slight, imperceptible change in your own

behavior and perception. That *is* the product. It changes what you do, what you think, and who you are."

Apple, Google, and Microsoft control the operating systems we use, while Facebook, YouTube, Netflix, and millions of apps supply the content that painlessly but mercilessly hijacks our attention. At the height of Netflix's reputation, chairman and CEO Reed Hastings admitted that sleep was the company's top competitor. He wasn't concerned about Hulu, Amazon Prime, or HBO Max siphoning off profits. "Think about it, when you watch a show from Netflix and you get addicted to it, you stay up late at night. We're competing with sleep, on the margin . . . and we're winning!"[19] But binge-watching supplants hours normally devoted to fitness, socializing, and sleep, making it a health hazard. Binge-eating and binge-watching often go hand-in-hand with sedentary behaviors linked to heart disease, stroke, and type 2 diabetes.[20] Watching television does have positive aspects. The problem emerges with unbridled indulgence and its associated downside.

Netflix has data to back up its binge-inducing power: there is a 75 percent chance you will binge-watch an entire series once you have seen the first two episodes. "Binge-racing" fans try to devour an entire series within twenty-four hours of its release, behavior the company promotes for the "unique satisfaction" it brings, calling it a "sport . . . an achievement to be proud of and brag about."[21] The number of Netflix subscribers who put themselves through this marathon grew more than twentyfold between 2016 and 2019 to reach 9.4 million. The top countries that do it are Canada, the United States, Denmark, Finland, Norway, and Germany. Binge-racing "is a new status symbol," it claims. But perhaps the habit is prevalent because it activates that part of the brain responsible for rewards. Thirty-seven percent of Netflix users have binge-watched at work. Over 50 percent of all adult TV viewers (including college students) have stayed awake all night to watch a show's entire season.[22]

At George Washington University we give each new medical student an iPad and a personal Google drive loaded with textbooks, assignments, and resources (though most students still prefer hardbound physical books because they are more conducive to remembering the material they read). These future doctors belong to a generation that grew up with digital devices. Yet they too are acutely aware of the downsides of daily screen engagement and the effort required to cope with them.

It is both a blessing and a curse that smartphones and tablets rarely leave our sides. More than fifty years ago, science fiction writer Isaac Asimov predicted what life would look like in 2014. "The lucky few who can be involved in creative work of any sort will be the true elite of mankind, for they alone will do more than serve a machine."[23] These biomechatronic devices simultaneously enhance neurological faculties (supplementing memory) even as they diminish them (by reducing focus and fragmenting our attention). They present a dilemma: Should I delete my Instagram account because it wastes so much time or should I interrupt what I'm doing now and check my likes (a reinforced behavior that is linked to reward)? Screen devices let us do what we could never have done in the past even as they exact a cost in depleting a finite mental resource: the fixed amount of energy we have for thinking, memory, and focus. Even if we resist the temptation to check a screen, brain drain still occurs because it is simply there, ineluctably sucking up our attention and taking a mental toll.[24]

Evasion characterizes the tech giants. Apple, Google, and others have reluctantly admitted, but only under the glare of scrutiny, that their products are indeed addictive. Historically, Mark Zuckerberg's response for years has typically been to evade responsibility. He claimed to be helpless to prevent Facebook being overrun by Russian disinformation in the runup to the 2016 presidential election. Resorting to the passive voice—always a sign of blame shifting—he said, "For the ways my work was used to divide people . . . I ask for forgiveness and I will work to do better."[25] He continued to make empty promises, and *The Wall Street Journal*'s deep reporting on "The Facebook Files" seriously damaged his company's credibility, now called "Meta."

Apple boasts rosy academic outcomes it attributes to its technology. But it misleadingly extrapolates miniscule data from a single school to all of K–12 education.

In a seeming act of penance tech giants have thrown apps at the problem as if the disease were also the cure: more technology to remedy the damage they wrought in the first place. But tech-based distraction management has been a bust: users thwart software barriers just as alcoholics and addicts circumvent well-intentioned efforts to limit their access.[26]

Screen absorption is not merely counterproductive. It fundamentally alters cognitive development in young generations because the brain does not fully mature until age twenty-five or so. Screen exposure typically

begins in infancy and has now surpassed traditional play and in-person social engagement as a child's single most frequent experience. The brain adapts exquisitely to every niche because from birth onward it is highly plastic, that Greek-derived word that means "moldable." Plasticity is why all brains, but especially young ones, change continually in response to whatever environment they find themselves in. Experience influences neurological development, alters the way genes express themselves in the brain, and sways the brain's long-term maturation. This is how cumulative screen exposure plastically changes brain structure and function. Tech companies know this as well and yet shun responsibility for any harm done.

Prolonged screen viewing is associated with reduced volume and delayed development in the microanatomy of brain regions such as the frontal lobes that govern impulse control, also a key aspect in addiction.[27] Not all individuals are equally predisposed to substance or behavioral addictions such as screen dependency. But addictions of all sorts do have a robust heritability of around 50 percent. Kids whose parents engage in high discretionary screen time are thus more likely to succumb to screen dependency themselves.[28] Because twenty-first-century technologies have transformed the social climate in which we live, the brain and mind are likewise undergoing unprecedented changes. Baroness Susan Greenfield, a neuroscientist and former director of Britain's Royal Institution, coined the phrase "mind change" to signify how computer games, the internet, and the spectacularly misnamed social media have changed the brain in ways both good and bad.[29]

I have cited some of the many benefits of smart devices. Among the negatives is stifling the sound of one's own thoughts. The mindset of individuals who grow up in this screen-saturated, constantly connected century will be characterized by:

- A reduced attention span, combined with a need for personal attention;
- Recklessness and a premium placed on sensation at the expense of sequential, reasoned thought;
- Increased susceptibility to addictions of all sorts;
- Poor to absent person-to-person skills, leading to . . .
- Isolation, indifference toward others, cruelty, and bullying;
- Virtual autism (i.e., autism-like behaviors induced by heavy screen exposure); and
- A shaky sense of identity

In later chapters I discuss positive intermittent reinforcement, a well-established psychological mechanism that perpetuates a particular behavior. Think how slot machines persuade players to keep feeding in money despite many near misses and outright losses. Software engineers use the exact same psychology of intermittent reinforcement to keep you tethered to a screen. Candy Crush was a wildly popular, highly addictive game once played on smartphones by more than 100 million daily users (other fads have since taken over, which is the nature of fads). Candy Crush is addictive because it doles out intermittent and unpredictable rewards such as arbitrary points, avatars, boosters, and blockers that are emotionally satisfying enough to keep users engaged. The satisfaction it induces is no different in kind from the fuzzy glow addicts feel while using.[30] The ability of recurrent screen stimulation to infiltrate ordinary perception is illustrated by one avid Candy Crush user who started seeing Candy figures from the game in his peripheral vision after suffering a stroke.[31] We do not yet know whether such brain changes are temporary or permanent, but the fact that screen games can alter the brain this way is unexpected and concerning.[32]

Bassinets, training potties, and car seats now come equipped with iPad holders. Either manufacturers have not thought through the consequences of blocking the developing central vision of a young child with unnatural mediated images or they don't care. In the West, a third of infants under age one currently play with smartphones and tablets. By age two almost all are interacting with digital devices despite warnings from pediatric experts that repetitive screen exposure, especially from fast-paced games and animations, can foster addictive behavior.

Why does this worry me? Because in 2020, diffusion tensor imaging (DTI) established a correlation between increased screen use in prekindergarten children and lower structural integrity at the microscopic level in their brain's white matter tracts that support language and developing literacy.[33] We need further study, but the immediate implication is that screen exposure is causing these changes during early stages of brain development.

It is but a short step from phone and game addiction to the consequences of social media that displace face-to-face interactions. Linguists tell us that words alone convey only 10 percent of an encounter's meaning, which is why we grasp context much better when engaged face-to-face than on the phone. Much meaning depends on vocal intonation, mutual eye

contact, body language, and touch—none of which is available to online social networks. Without having the opportunity to rehearse social skills and nonverbal communication, how can one hope to read other people, let alone empathize with and understand them? An entire issue of the *Atlantic* explored why hook-up culture has supplanted dating and romance among young adults. "We hook up because we have no social skills. We have no social skills because we hook up," complained one coed. Another agrees: "We'd probably have a lot more sex if we didn't get home and turn on the TV and start scrolling through our phones."[34] Mobile technology, which Gen Z has never lived without, has acted like a security blanket but has also hindered Gen Zers from developing face-to-face skills and resiliency in the inevitable face of failure.[35]

Tech's cool factor dazzles millions. Many celebrate that the digital realm is "free." But as behavioral psychologist B. F. Skinner warned decades ago in *Beyond Freedom and Dignity,* "A system of slavery so well designed that it does not breed revolt is the real threat."[36] Addictive screen media now constitute a slave economy with users as the labor. Advertisers are the paying customer, social networks and media platforms are the store, and your eyeballs and brains are the commodity on offer. Repeatedly we are sidetracked and manipulated by a handful of companies that steer what three billion people—more than 30 percent of the planet's population—think and do every day. Even the most repressive theocratic and authoritarian regimes don't hold such sway.

A cautionary legend pertinent in this era of digital indulgence is Goethe's folk tale "The Sorcerer's Apprentice" (*Der Zauberlehrling*). Popularized in a later version by Disney's *Fantasia*, it tells of an ageing sorcerer who leaves his apprentice to finish his chores for the night. Weary of fetching pail after pail of water, the apprentice enchants a broom to carry them for him by using magic in which he is not yet fully trained. The apprentice panics when he does not know how to stop the enchanted broom—a tool he believed would lighten his workload—as it begins to flood the workshop with bucket after bucket. The apprentice hacks the broom to pieces only to see each piece grow into a separate new broom that fetches even more water at terrifying speed. Just when all seems lost, the old sorcerer returns to break the spell.

What will it take to become like the wise sorcerer who halts the chaos when automatic newsfeeds, "recommended" videos, and "people you may

know" constantly vie for your attention? How can you prevent your private data from being repurposed and redirected to "personalized" advertising, conspiracy theories, biased news, rank misinformation, and an echo chamber of outrage and indignation aimed to narrow your point of view without you even realizing what's being done to you? Partisanship or ideology isn't the problem. The problem is the biological limits of attention and the fact that the digital world has already taxed it beyond the breaking point.